LOSSES

IN

GOLD AMALGAMATION.

SECOND EDITION.

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IN

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GOLD AMALGAMATION:

WITH NOTES ON THE CONCENTRATION OF GOLD AND SILVER ORES.

(WITH SIX PLATES.)

BY

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SECOND EDITION.

E. & F. N. SPON, 125, STRAND, LONDON.

PREFACE.

THE purpose of the following notes is not to give
a detailed description of milling processes and
machinery, but to offer a little useful knowledge
to directors of English gold mining companies
on some of the simple principles that are too often
ignorantly, or designedly, ignored, or surrounded
with mystery by inexperienced mine managers;
also to give to millmen a few suggestions, founded
on a tolerably wide experience, in the commercial
handling of many kinds of ores. Some directors
of mining companies are naturally inclined to listen
to the specious promises of inventors of novel
processes and new machinery, forgetting their own
personal disadvantage in any argument on such
matters, and assuming a confidence in the logic
of their own conclusions, while they ignore the
fruitful experience of thousands of practical men
who are engaged in the mining business. The
repeated failures of directors in sending out new
machinery to their mines, ought by this time to be
a sufficient warning against increasing risks that
are at once natural and unavoidable, and to deter

them from plunging their shareholders into experiments which, in ninety-nine cases out of a hundred, result in nothing but excessive and needless expense.

It is certain that new machines and new processes are, and will be, given attention by mining men in proportion to their probable merits; but the proper place for experiments is in a mill already as successful as known processes can be made. In a new enterprise, even when the expense of an experiment is undertaken by the inventor, the loss to the mine owner in case of failure must be very great, both in time and general running expenses. Directors should not believe that a willingness to risk cash in proving an invention is necessarily any proof of value of the same : it is only a measure of the faith of the inventor, which is hardly a safe standard by which to risk shareholders' money.

The variety of modifications in approved processes to which reference is made, ought at least to suggest the desirability of exhausting the known before drawing on the unknown and purely speculative. It should also be borne in mind, that what might appear at first sight to be new processes, and even new machinery, are in fact, often nothing but old contrivances and plausible theories long ago exploded among practical men.

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LOSSES

IN

GOLD AMALGAMATION.

PART I.

———

BEFORE attempting to lessen a stated loss in gold amalgamation, it is necessary to establish exactly (1) the amount, and (2) the form in which it occurs. Although copper-plate amalgamation is not a perfect system, it is much better in results than many inventors of new processes believe. It is very common, as an introduction of new machines or processes, to state, on the strength of some ancient Government report, that the loss of gold in milling is from 30 to 50 per cent. This is simple nonsense as a basis of calculation for improvements. In the first place, Government reports on mining results are not necessarily reliable, except perhaps as to product in some places; and the miners always know their business well enough to get their own ideas incorporated in the reports of Government officials. It can generally be assumed that the owner of a mine is willing to have his tailings assay as high as possible in reports : it makes his ore so much the

richer, and leaves a good ground of argument for
increased value of property if the purchaser will only
put in more perfect machinery. However, the
question of Government reports is not worth con-
sidering, because even they at present do not show
anything like the losses which are seen in the reports
of fifteen years ago, still quoted by inventors. For
example, a simple reference to the California State
Mineralogist's reports will show that tailings assays
in modern mills average now from $\frac{1}{4}$ to $1\frac{1}{2}$ dwt. per
ton.

The following table gives results at a few typical
gold mills, and will be interesting as an offset to
the frequent outcries about universal losses in gold
milling :—

Name of Mine or Company.	Average of Ore.	Assay of Tailings.	No. of Stamps.
	dwts.	dwts.	
Homestake Company ..	4 to 4$\frac{1}{2}$	$\frac{1}{7}$ to $\frac{3}{4}$	120
Alaska Mining Company ..	5	$\frac{1}{7}$ to $\frac{3}{4}$	240
El Callao	25	3$\frac{1}{2}$	60
Yuba	8$\frac{1}{2}$	$\frac{1}{2}$	15
Plumas Eureka	7$\frac{1}{2}$	1	60

In California, on a considerable variety of gold
ores, the percentage of gold saved averages 80 to
85 per cent., and most careful daily tests in some of

the best gold mills using concentrators show 85 to
90 per cent.

It is perfectly obvious, if mill tailings are aver-
aging in value 2s. to 3s. per ton by the cheapest
and simplest of all processes, that the chances of
improvement are very slight for the inventor, ex-
cept in mere matters of economy, of handling the
ore, and wear of machinery; therefore the very first
essential of improvement is to find out exactly how
much room there is for it. In this connection some
of the reports of mine managers and directors are
very amusing. The assay of the tailings is often
assumed to be the difference between what the ore
is supposed to contain and what it actually yields.
The value of the ore is itself arrived at by various
and extraordinary methods; such as reference to the
report of the expert on which the mine was pur-
chased; the returns of occasional assays by mine fore-
man of good ore; the results of neighbouring mines
on the same vein, &c. Or again, actual assays of
tailings are taken, but from such samples that they are
equally worthless as the estimates of ore value. It
is very common for a sample of tailings to be dug
out of a pit where it has been concentrating by the
flow of pulp for weeks; or from the bed of a river
below the mill, in which latter case the greater the
distance down the stream the more damning are
results presumed to be against the mill. In still other
cases, where regular proper samples are taken as

tailings flow, and those samples give low assays, they
are doubted, on the ingenious supposition that the
gold has floated off with the water, or evaporated
in the steam if boiled down to dryness: every
theory, in fact, except the fact alone useful to know,
that the ore working on a large scale is of lower
average value than was supposed from assays in the
mine. It often happens that in starting work on a
mine with a small stamp mill, the yield per ton of
ore is for a time satisfactory and up to calculations,
because the mill can be supplied with ore from the
best portions of the vein; but on adding a larger
mill the conditions are all changed. The mine
must be then worked regularly and systematically,
and the large consumption of rock by the mill
makes it impossible to pick out the ground as
before; consequently the yield per ton runs down
at once. This simple explanation of lower yield is
often kept out of sight by specious assertions as to
large loss in tailings. The late experience in some
African mills illustrates this fact by figures that can
be understood by the most inexperienced, and these
figures—from two well-known mines, the Robinson
and Jumpers—are as follows:—

The Robinson mine for several months produced
in the neighbourhood of 4000 oz. of gold with
10 stamps. When 30 more stamps were added,
the yield of gold was 8000 oz., from more than
four times the quantity of ore formerly producing

4000 oz. In other words, the grade of the ore dropped 50 per cent. when the crushing capacity was increased four-fold.

The Jumpers mine, in its first workings, on 28,000 tons of ore, gave an average yield of 20 dwts. gold per ton. In six months' work with 30 stamps, the yield was 18½ dwts. The result of the first month's run with 70 stamps gave 11¾ dwts. per ton; and the second month's run with 70 stamps, 10¾ dwts. In these two cases, the management being good, no question of increased loss in tailings has arisen; but in many smaller mines such explanation would be jumped at by directors, and inventors of new processes would be listened to respectfully.

As to the loss that does occur in gold amalgamation, it is very easy to determine both the quantity and form of loss, equally necessary to be known before proceeding to improvements. Small samples are taken from the waste outflow of the mill—or separately of the different batteries—at regular intervals, until a bucketful is collected, which is allowed to settle for several hours, the clear water poured off the top, and the residue evaporated to dryness; then well mixed, sampled, and assayed. Even in the dipping out of each small sample, an error may be made if the vessel be allowed to overflow, so producing a concentration of heavy sand and mineral. Samples properly taken in this

way daily, and averaged up, will establish the assay value per ton of tailings; and the samples have then to be examined to determine what state the gold is in. An automatic sampler for mill tailings is of great utility, and more reliable than the irregular sampling by some employé, as is usual. The loss will be in one or more of the following forms:—

(1) Loss of free gold, quicksilver, or amalgam, all due to careless or inexperienced amalgamation.

(2) Free gold and gold-bearing sulphurets, attached to or imbedded in particles of rock.

(3) Gold contained in base metal sulphides, broadly termed "sulphurets."

(4) Gold in the fine slimes.

(5) A condition of gold in which it is not susceptible of copper-plate amalgamation.

The inventors of new processes usually ignore these distinctions. It may happen that experiments show a good result on a certain ore because the loss of gold occurs in a certain way, and the inventor of limited experience hastily assumes from his results that the process is equally applicable to all gold ores, irrespective of the differences in their characters and conditions of the gold loss. The first test is to determine under which of the above heads the serious loss occurs, for some loss may be found in each class; and a process which may be effective on fine gold, for instance, may be utterly useless on sulphurets, and *vice versâ.*

A fair average of the daily tailings samples is examined as follows :—

(A) It is panned down very carefully, to determine if free gold, or amalgam, or quicksilver is to be seen. If any of these are found, no further tests on tailings samples are necessary until the man in charge of the amalgamation is replaced, or instructed in his business. In making this simple test it must be borne in mind that evaporating the tailings at a high heat may drive off any fine quicksilver. It is to be noted that the use of quicksilver wells in front of the batteries is a cover for careless or inexperienced work: with plates immediately below the screens a perfect index is afforded of work inside the battery, and of the proper proportioning of quicksilver feed or the contrary ; while the quicksilver well hides the fact of an excessive feed of quicksilver or the reverse, for some time. The gold that can be caught in a quicksilver well would not escape the plates alone, if these be in good condition.

(B) A quantity of the average sample is sized on screens, say 60-mesh and 100-mesh brass wire cloth, and each of the three sizes so obtained weighed to determine their relative proportions, and assayed separately. If the portion remaining on 60-mesh assays quite appreciably above the finer sizes, the loss by imbedded gold can be diminished only by finer crushing, either in the battery, or outside by

a subsequent grinding, to be treated of later
The coarse portion on the 60-mesh should
ground finer in a mortar, and panned, to see if
loss is in free gold or sulphurets, as this would h
a bearing on what batteries and coppers alone wo
do by finer crushing.   Should the assays sh
approximately equal value in the coarse as in
finest particles, it is clear that to use a finer scr
in the battery would simply diminish capaci
without materially increasing the percentage sav
If the slimes below 100-mesh assay higher th
the other sizes, a coarser screen in the batt
will probably give better commercial results,
increased capacity without increase of loss.

(C) A weighed portion of the average tailir
sample is next vanned or panned down, to determ
if any sulphurets exist, and if so the percentage of
same.   The sulphurets washed out are assayed,
establish their value with reference to commer
treatment after concentration.   The weight a
assay value of sulphurets, calculated on the weight
sample washed, will give the value per ton of origi
tailings saved in the form of sulphurets.   In t
test, of course, it is assumed that test (A) has b
previously applied, because imperfect amalgamat
would vitiate the sulphuret concentration test
introducing amalgam into the concentrates.   T
concentration test requires more skill to make th
the preceding, because the fine sulphurets are

no means easy to save close by a hand test. The
tools used for this work are shown on Plate I.
If an ordinary gold-pan be used to wash with, the
process must be repeated at least three or four
times, washing from one pan into another and
back again, and collecting each time the sul-
phurets; for the gold-pan is a very imperfect
appliance for saving fine mineral, and a Frue vanner
in practice will give both cleaner concentrates and
poorer tailings than a hand test will show. The
Cornish vanning shovel is a far better tool than
a gold-pan for sulphurets, but not so good for free
gold or amalgam. The angles of the sides of a
gold-pan collect the free gold, but cause a dis-
turbing ripple in the water when washing sulphurets,
which floats them off. As a curious instance of
ignorance of this fact, it is sometimes claimed by
inventors of concentrators for sulphurets, that they
have imitated the action of a pan; and it only needs
the washing of tailings from a pan to show how
poor a tool it is for sulphurets, even when it has
a head over it, which a machine cannot replace.
The vanning plaque is a circular flat curved dish
of sheet iron, enamelled white all over, to prevent
rust and to show up better the colour of the
sulphurets. In shape it is practically a vanning
shovel without a handle, but, like the latter, it
requires a special skill in its use, obtained only by
practice. Its advantages are, white surface, freedom

from rust, and convenience of carriage, as it will go
in an ordinary valise. The Mexican batea is also a
very good tool for hand tests, for both free gold
and sulphurets, and requires much less skill for
collecting the mineral than a shovel or a plaque.
This tool can now be obtained of enamelled iron,
which, while perhaps not as perfect for catching
some flakey gold as the rougher wood surface, is
better than the latter for concentrating sulphurets,
and equally good for fine gold. A steady circular
shake without revolving, alternated with a recipro-
cating circular motion, settles all heavy mineral into
the central depression, and an immediate rapid wash
of the water towards one side carries off the sand
in a fan-shape to the edge, leaving the gold or
sulphurets showing at the apex of the cone of
material. For hand tests on a weighed quantity,
it is very convenient to drill a small smooth hole,
say ⅛ of inch, in the very centre of the batea, and
put a small cork or wooden plug in from below, flush
with the inside surface, to close while settling and
spreading; then remove the plug, holding the batea
over an evaporating dish, and wash down through the
hole by a fine jet from a wash bottle, all the clear
mineral showing. The plug is then again put in
a little water put on the batea, and the material aga.
well shaken, settled, and spread, and the mineral
washed out below; the process being repeated until
no more mineral can be separated. A flat-shaped

evaporating dish is sometimes used for these hand
tests, but it is difficult to get one of good form, as
any slight shortening of radius of the curve near
the edge is fatal to good work, by necessitating a
steep inclination to wash off the sand.

(D) The total losses from fine gold in the
slimes, are practically covered already by the sizing
test (B), which will give the proportion in the
slimes below 100-mesh, but in this would be
included a loss due to sulphurets, which can be
avoided in large measure by concentration. A very
careful concentration test on the slimes alone will
then establish the approximate loss due to fine gold.
This loss of fine, or " float " gold as it is often called,
when its limits are established by the above tests, will
usually be found, on calculation of percentage of
weight involved, to be less serious than imagined
on most gold ores.

(E) To determine whether the fine gold in the
slimes is amalgamable by a more effective system
than copper-plate process, is only worth while in
cases where above tests show that there is a probable
commercial advantage in adopting a more com-
plicated process ; for it is ridiculous to lose sight
of the question of profit in the search after a
perfect result. Where the loss is very high in
the slimes, it will doubtless be found also high in
the coarser sizes of tailings ; and, as a consequence,
it becomes really a question of another system of

treatment for the original ore, not solely of the
slimes; it can therefore be treated under the head
of "gold in a condition not susceptible of amal-
gamation on copper." The best test of the highest
amalgamation obtainable is by use of an amalga-
mation pan, either large or small. Small laboratory
pans are made, which can be run either by hand or
from any running shaft, and will take a charge of
3 to 5 lbs. of ore. These small pans, if properly
constructed and run, will give results closely
approximating mill work by pan amalgamation.

THE TREATMENT OF GOLD ORES.

THE above examinations and tests, if carefully carried out, will determine the actual average loss of gold on the mill tailings, and the form in which it occurs, as a necessary preliminary step to adopting improvements which will now be considered. The possible improvements will divide themselves, according to previous divisions of the loss, into :—

(1) The employment of greater skill in copper-plate amalgamation.

(2) The freeing of the gold locked up in rock particles.

(3) The concentration and separate treatment of the sulphurets.

(4 & 5) The adoption of a more effective system of treatment. ·

No arbitrary division can be made of these, as more than one of the remedies may be necessary in any given case, but it is simpler to treat them separately for convenience of reference.

(1) SKILFUL AMALGAMATION.

It is not possible to supply the lack of skill and experience by instructions, and the owners of mills should take the only safe course in this part of the

for the ores; and therefore what follows on the matter of special improvements can be justified, as drawn from a wider knowledge of difficulties met and overcome than some good gold amalgamators have.

As a possible means of slightly increasing the amount of gold amalgamated, a shaking copperplate with riffle is to be recommended. The so-called "amalgam saver" attached to the feed distributor of the Frue vanner, is simply a short strip of electro silver-plated copper, which, being attached to the shaking frame of the machine, moves with it, and the pulp flowing over it has a chance of depositing some fine gold by the shaking motion effecting a contact of the particles with the surface. An ordinary fixed copper-plate requires from $1\frac{1}{2}$ to 2 inches fall in the foot to keep it clear of sand when the plate is full width of the battery; but if a short quick shake be given the copper it will keep clear and do good work with an incline of $\frac{1}{4}$ to $\frac{1}{2}$ inch to the foot. Electro-plated copper is better than plain copper for these auxiliary plates, which can be swung on a light wooden frame and driven by a crank shaft placed on one side with a throw of about 1 inch at right angles to direction of pulp flow, and making 150 to 180 revolutions per minute. At the top of the copper-plate, a strip of wood $\frac{1}{2}$ inch thick should be nailed across the full width between sides of table, forming a

riffle, behind which a light body of the coarser sand
and sulphurets collects, and remains in lively mo-
tion by the shaking action, so forming the most
effective contrivance for catching quicksilver or
hard amalgam which has yet been devised. Should,
by accident or neglect, the inside coppers suddenly
harden and chips of amalgam escape by the screen,
small pellets and marbles of clean hard amalgam
will be found behind this riffle, rolled up by the
shaking motion, and increasing in size just as a snow
ball will when rolled in snow. It will pay well, in
some cases, to use a number of these shaking
coppers, 4 feet wide and 4 feet long, dividing the
pulp of the upper coppers thinly over them, to
increase the chances of contact with the fine gold
particles. The copper is better used in giving all
the width possible, rather than length of plate : a shee
of copper 4 feet × 8 feet will save more gold if mad³
into two shaking tables 4 × 4 for 5 stamps, than a!
one table 4 × 8 feet. This shaking table arrange⁻
ment has much to commend it, and was used by
the writers in Montana in 1878. It is now used in
some mills in California with marked success. In
the case of one mill, Mr. J. H. Hammond, M.E.,
reports a saving of 10*l.* worth of amalgam per
day, below the ordinary copper plates. A sketch is
given on Plate IV. of a convenient form of shaking
copper with amalgam riffle, supported on four
short rocking legs. The table can of course be

hung on rods from above; but is then not quite so clear and convenient for cleaning up.

Blanket sluices are still used in many places, and their chief advantage lies in the fact that when set at the proper inclination for the ore and frequently washed, they will save fine amalgam; but used as they sometimes are for the concentration of sulphurets, they cannot be defended. Even as amalgam-savers the shaking coppers and riffles are much to be preferred, as giving an available product of amalgam, not a mass of sand and sulphurets containing some specks of amalgam. If sulphurets are worth saving, they are worth saving in a comparatively clean form; not necessarily by so perfect a machine as the Frue vanner, but at least by some simple form of concentrator free from the defects of the blanket sluice, which, if set to save fine mineral, becomes clogged up very quickly with coarse sand. In 1873 it was a very general practice in California to use blankets, and some form of pan or other amalgamation for working up the blanketings; but this process has practically gone out of existence in the United States, owing to the evident advantages of simple plate amalgamation, and close concentration of the sulphurets, if any occur in the ore.

(2) FINER CRUSHING.

The immediate suggestion of the discovery of free gold in the coarser rock particles, is to use a finer screen in the battery; but there are disadvantages to be also considered in this simple remedy. The finer screen will at once diminish the capacity of mill, i.e. increase cost per ton of milling, and probably decrease monthly yield of bullion—and may increase loss of gold in slimes, and also of fine sulphurets where the ore contains base metals. There is in all cases a compromise point between excessive loss and highest saving, wherein the best profit of milling will rest; this point depends on local conditions of cost of working, and value and nature of ore, so that only experiment can determine it. There is, however, a method which promises in some cases to allow of large capacity and the maximum saving by copper-plate amalgamation. This consists in re-grinding the coarser part of the tailings and again amalgamating. The separation is effected either by shaking or revolving screens; or simpler still by hydraulic sizers. In this latter arrangement a small pointed box is employed, with an upward jet of water, which prevents any but the heaviest and coarsest pieces from discharging at the bottom opening. The tailings flow into and out of the box, and the regulation of the quantity of water flowing controls the size of the particles

rged at the bottom. A cut of this apparatus
wn on Plate III. The coarse portion, dis-
d from the lower opening of box, goes to
ding machines — such as Heberle mills,
ngton mills, arastras, grinding-pans, &c.,—
en again over copper plates, to extract the
reed by the grinding of the rock particles.
ntroduction of the excess of water by the
lic sizer in the overflow portion, may cause
nconvenience should concentration be after-
used, and in such cases large pointed settling-
can be used to again separate this excess of
as illustrated in Plate II. and described under
ad of Concentration. Trouble under this
an be avoided where battery screens are not
oarse, by concentrating before the separation
se from fine is effected.

advantages of this procedure, when possible,
parent. A comparatively coarse screen can be
or the stamps, a large capacity be attained,
ssary grinding of gold and sulphurets
d, and yet a fair percentage of both free gold
lphurets be extracted. There is practically no
n to the machinery, except the grinding-mill
mall quantity of material per day ; the settling
require no attention if built properly, and
e made by any carpenter on the ground.
g established the process, the battery screens
e tried coarser and coarser till the proper

limit of economy is reached.   In many cases mill-
men will make more profit by attempts to use
coarser screens than finer.   When the ore contains
a large percentage of sulphurets, the advantage of
the method described is added to by the decrease in
proportion of slimes produced for subsequent con-
centration, and in such cases the concentration
machinery is modified for treating the coarser
mineral, as will be described later.

The use of the hydraulic sizer is very simple, and
its various forms and regulations are described more
in detail on page 63.

(3) CONCENTRATION.

The close and automatic concentration of sul-
phurets is the most marked improvement of late
years in treating gold ores.   The copper-plate
process itself has practically been unchanged for
years, though great improvements have taken
place in the construction details of mills, so that
increased capacity and greater economy of handling
ore have resulted.   But the close concentration of
sulphurets, and subsequent treatment of the same
after roasting, has, more than anything else, lessened
the average loss of gold in milling ; so that taking
out a few exceptional ores, gold mill tailings now-
adays need not be of any commercial value, as
shown in the table already given above.   The

application of concentrating machinery is of course
limited to ores in which the quantity and value of
sulphurets will justify the separating of them and
subsequent treatment; and a very large proportion
of gold ores do contain sulphurets of noticeable
value, which may not appear in the oxidised surface
portions of the deposits, but come in later with
depth. As already pointed out, it is a simple
matter to determine by hand tests and assays
whether concentration is desirable or not on any
given ore; and, having decided in the affirmative,
the practical execution of the work is twofold:
1st, the actual separation of the sulphurets in the
form of clean concentrates; and 2nd, the treatment
of the concentrates obtained. As the question of
concentration will be treated later on under Part II.,
and as the concentrates, from their nature, come
under the heads 4 and 5 of More Effective Treat-
ment, it is only necessary here to make some
general remarks under the present head.

The process of concentration requires no descrip-
tion, and the machinery used is pretty generally
known. It can be safely stated—without going
into descriptions of dozens of new machines which,
like the pulverisers that come out to displace stamps,
are heard of for a little then drop out of sight
again—that where sulphurets are of such value as
to make close saving necessary, the Frue vanner
and Embrey concentrators are always used in

modern mills; but if sulphurets are low grade, and the object is simply to collect most of them for rough working in pans or sale to smelters, simpler and less perfect appliances will answer, such as blanket sluices, bumping-tables, and buddles. It is sometimes objected by inexperienced millmen that the more perfect concentrators require too much skill, or are too expensive to put in place; but the question cannot be disposed of by such surface reasons: the actual points are, that if sulphurets will pay to save close, it is absurd to adjust the machinery to the men employed instead of choosing the men with reference to machinery which must be used; and again, the matter of cost must be one of expediency, and interest on money invested. There is no difficulty now in engaging men of thorough experience in handling concentrators, and one man can as easily overlook twenty machines as one, and break in other men to the work as well. Of course where profits from sulphurets can only be small, there is no reason for installing an expensive floor of concentrators; and bumping-tables or revolving buddles will answer the purpose. However out of the way a mining camp may be, and however poor the native labour, there is no reason why skilled men should not be employed in directing the mining and milling; and the company which submits to inferior skill to save paying the necessary salaries, will require a rich

mine, and good backing of luck as well, to prevent failure.

The disposition of sulphurets, when obtained by concentration, depends on a variety of circumstances; and in some mines, where certain streaks consist of nearly solid ˋmineral, or where the sulphurets come in smaller or larger pockets easily distinguishable from the bulk of the quartz or other gangue, it is often advisable to pick out at the mine the solid mineral and add this to the concentrates, rather than let it go through the batteries and be subject to the loss in free gold and sliming of the mineral. As a rule, the process adopted for the concentrates will yield a˛ higher percentage than the simple milling and concentrating process, so there is an advantage in adding the hand-selected richer ore of the mine to the concentrates. In certain cases of coarse gold being present in the solid mineral, which would complicate subsequent treatment by chlorination, it may be better to let the mineral go into the mill with the bulk of the ore, as the sliming of mineral would be the lesser of two evils. Whenever the neighbourhood of smelters or cheap transportation allows, it is desirable to sell the concentrates, as usually good prices can be obtained, and credit sometimes be received for lead, copper, or iron in the sulphurets. Generally, however, smelting is not available, except as a local treatment simply for the

sulphurets as described under heads 4 and 5, in
place of chlorination. Frequently the choice of
treatment will rest between some form of chlori-
nation, and amalgamation after roasting; and in
certain exceptional cases even, pan or copper-plate
amalgamation is necessary after chlorination, in
order to save some coarse gold escaping the first
process. Chlorination is in most cases preferable
to all others for the ordinary sulphurets of gold
ores. There are various modifications of the
process, the advantages of which are simply
dependent on relative costs of chemicals and labour,
and the quantities to be treated daily.

(4 & 5) MORE EFFECTIVE PROCESSES.

The ores which cannot be economically treated by
simple copper-plate amalgamation, with or without
concentration, must be relatively richer than the
average of free-milling ores—which can be taken
perhaps as an average all over the world of some
10 dwts. per ton—or they cannot be treated at all
in most mining camps. Where an ore, from its
contents in silver, lead, copper, iron, lime, &c., is of
intrinsic value, outside of the gold contents, for
other metals, or as a flux for other ores, a very low
gold assay may be realised; but putting aside the
cases in which the nature of ore and proximity of
smelting gives a fluxing value, we can divide the

gold ores not susceptible of copper-plate process into the following groups :—

(A) Comparatively high grade ore, in which the gold will not amalgamate to a fair percentage, although little or no sulphurets are present.

(B) Ores which contain large quantities of sulphurets.

(C) Exceptional ores, in which the condition of the gold is unknown.

It will facilitate explanation to describe these groups separately.

(A) FREE ORES.

In many of the higher grade gold ores the metal is very finely divided through the rock, and seemingly to this alone is due the excessive loss experienced in the regular process. In some such cases the gold is alloyed with silver, and worth very little per ounce of bullion. The question of fine crushing and of re-grinding has already been touched on, and therefore it is assumed that such remedies have been found insufficient for the ores under discussion now.

After copper-plate amalgamation, the next simplest and most economical process is that of pan amalgamation, which is adopted either on the raw or roasted ore. Usually roasting of gold ores is unsatisfactory as a preparation for amalgamation, and puts part of the gold in a condition most

unfavourable for allowing contact with the quick-
silver; besides involving often a loss of gold in the
actual roasting, sometimes even to a very marked
extent.   In roasting some gold ores it is found ad-
vantageous to add a small percentage of salt to the
charge, but on other ores this increases largely the
loss of gold by volatilisation.

In some exceptional ores, such as described page
87, where there are practically no base metals present,
roasting can be adopted without these ill effects;
but even then its commercial advantages must be
carefully considered.   The roasting operation is
frequently effective in softening and cracking the
hardest rock particles, so as to facilitate grinding in
the pan, and consequently improving the amal-
gamation.   This is also found to be the case in
preparing a free ore for chlorination, as the gas
will better penetrate the particles and attack the
imbedded gold.

The old-fashioned stone arastra, though slow,
is an excellent amalgamator of fine gold; and
there are circumstances in which this simple and
readily-built machine is well worth the considera-
tion of the millman on either raw or roasted ores,
as giving a greater efficiency than an iron pan.

The raw pan amalgamation is conducted either
by the old tank system, or by the modern con-
tinuous process.   In the former, the crushed ore is
run into large shallow settling tanks, which are dug

out by hand and charged into the separate pans; while in the continuous process, the pulp runs through a line of pans and settlers connected by pipes, so that no handling or settling of the pulp is required. The first one or two of the pans in the continuous system are specially arranged for grinding the pulp, as this is usually necessary. The extent to which pan amalgamation will succeed, can be determined only by experiment; and this can be tried by small pan charges in a laboratory pan, if a large pan be not available. In these experiments, as in actual work, the use of chemicals should be very limited; with gold very little, if anything, is necessary, and a little lime or cyanide of potassium will generally cover all requirements of keeping the quicksilver clean. The continuous process offers great advantages in economy of space and cost of working: very little labour is required, and several gold mines in the United States, as well as silver mines, are using the process with marked success. In the case of some gold ores carrying a small percentage of rich sulphurets, concentration is used before or after the pan amalgamation, and materially increases the saving effected. This combination process is especially available for mixed gold and silver ores, and is more fully treated of under the head of Concentration, at page 84. After the pulp leaves the last settler, it contains an excess of water for the concentrators, which

must be provided for in one of three ways, viz. :—by
settling in the large pointed boxes; by spreading
on a larger number of regular Frue vanners than
usual; or by the use of a smaller number of the
improved belt vanners, which can handle a greater
excess of water than the regular smooth belts, as
will be described later on.

Pan amalgamation not being available on any
given ore of the class under discussion, there re-
mains, broadly speaking, nothing but chlorination.
For working a few tons per day of concentrates, the
regular Plattner process, with fixed tanks and long
exposure to gas, is as convenient and economical as
any of the improved processes; because the plant is
simple and cheap to erect, and very few hands
necessary.   The production of the gas is a simple
question of relative cost of different chemicals
delivered at the mine.   When, however, it comes
to treating the crude ore of a mine by chlorination,
the conditions are changed, and there is a field for
improvement over the regular method of chlorina-
tion.   To work large quantities of ore daily, of a
necessarily lower grade than most concentrates from
mills, requires economy in crushing, roasting, gas
consumption, labour, and time employed.   There
are great differences of opinion as to the advan-
tages of using gas under pressure, and the best
methods of producing the gas and filtering off the

solution from the precipitated gold; but the use of revolving barrels in place of fixed tanks offers an economy in labour and time, and makes special watchful skill less important in the whole process than in the Plattner method ; so that one of the modifications of the barrel system would be naturally adopted on crude ore for extensive working. In regard to chemicals for production of the gas, claims are made of economy by the proposed supply of condensed chlorine at reasonable rates ; and the high cost of transportation to many mining districts opens a prospect for this improvement beyond doubt.

The effectiveness of bromine as a substitute for chlorine has long been known to metallurgists, but cost and difficulty in handling are against it. The cost has lately been reduced as low as 1s. per lb., which the Newberry Vautin Co. offer to supply it at, stating also that 5 lbs. will suffice for 1¼ ton charge of ore. This company has very recently much modified its process of chlorination, by working barrel charges nearly dry, using a barrel which is fitted with a filter for washing off, and by improvements in the manufacture and packing of chemicals to make the chlorine so as to reduce the cost and danger of transportation, which in the case of acid and chloride of lime are serious items.

At the Mount Morgan mine is the largest chlorination plant in the world. The ore averages

Sebastian mine in San Salvador a very large
ier chlorination plant was erected, the ore
crushed wet in Huntington mills ; then settled,
roasted, and " gassed." The disadvantages
et crushing and change in character of the
d to the abandonment of this process.
is particularly necessary in milling to keep
ich as possible to processes which have been
lly worked out in practice, as loss of time in
imenting and perfecting of details is often
serious, and this must be considered in ex-
ng the claims of all new, or so-called new
sses. It is also highly important that the
owner should not be led into hasty conclusions
the necessity of an expensive complicated pro-
imply from the results of the first few months'
ng of a mill, when rich ore only is worked,
inexperienced millmen employed, and no in-
ty has been exercised in modifying the details
: process to the peculiarity of the ore.

(B) SULPHURETTED ORES.

th these a larger field of treatment is opened
e admission of smelting processes of various
Generally the pan amalgamation process
be preceded by roasting. In the Colonies
ng and working in pans the raw partially
ntrated sulphurets is practised, but in the

United States this process has entirely gone out of
use, being displaced by smelting and chlorination,
rendered possible by the development of the
country and more perfect concentration.   Some
sulphurets contain their value in comparatively
coarse free gold, which grinding 'will liberate and
mercury attack; but most of the base metal sul-
phides in gold ores will only yield a small part of
their gold contents to such a process.   Even where
still in use, this process often has its chief excuse in
an imperfect concentration, and would be better
superseded by the close saving of higher grade clean
concentrates, properly treated by chlorination or
some modification of the smelting process.

As sulphuretted ores may comprehend all pro-
portions between the sulphides and the gangue, and
as treatment often depends on the relative propor-
tion of the two, it is better to divide into two classes,
which must necessarily be somewhat arbitrary, but
will at least facilitate description.   The following
divisions will therefore be taken :—

(1) Concentrating ores.

(2) Non-concentrating ores.

No sharp line of distinction can be made by mere
percentage of sulphurets between these two classes,
because average value and local cost of treatment
enter into the calculation; but, roughly speaking,
ores containing over 40 per cent. of sulphurets are
not fit for concentration.   Frequently an ore which

will average 20 to 50 per cent. of sulphurets as coming from the mine, is far better divided by hand selection into rich mineral of the 2nd class, and poorer ore for concentration. For instance, in a mine where seams and pockets of solid minerals occur, it may happen that 100 tons just as mined will contain 20 per cent. of sulphurets, and yet by a simple hand-picking this can be separated into 20 tons of 75 per cent. sulphurets and 80 tons of $6\frac{1}{4}$ per cent. sulphurets. Where this can be cheaply done, it is far better than submitting the whole 100 tons to the cost and losses of concentration, and it also renders possible a more expensive process than the original ore could sustain.

(1) CONCENTRATING ORES.

The gold in such ores is generally partly free and partly combined with the sulphurets. In speaking of the gold as combined with the sulphurets, the miner's sense of the term, rather than the chemist's, is intended. It is held by many authorities that the gold is seldom or never found actually in chemical combination—excepting in some antimony and tellurium compounds—but is in an exceedingly fine state of division mechanically intermixed with the base metal sulphides. But to the millman this view of the case is without importance, because as a matter of fact the mechanical division is so per-

fect, and the difficulty of grinding and avoiding the
influence of base metals so great commercially, that
roasting is necessary to free the gold. The term
" combined " is therefore used in this article as a
millman would use it, i.e. as meaning such a con-
dition that practically the gold is only it freed by
roasting or action of acids. In this connection it
may be worth while to remark that the p advocates
of new processes of gold extraction from. this class
of ore, based on assumed condition of ic the metal
itself, often fail to appreciate the fact of ; the mere
preliminary impalpable grinding being itself
equivalent to a commercial condensation of
the process, by necessitating use of grinding
machinery, which greatly increases the cost ove
ordinary processes.

If the gold be partly distinct from the sulphuret
as shown by an ordinary degree of crushing—sa
to 40-mesh—and the percentage of sulphurets do
not exceed 10, there is hardly any question at a
but that stamps, copper plates, and Fru e vanner
will cover the process required and give the be:
commercial results ; because this is the process now
used by the best and most successful millm' n all ove:
the world.   Of course, if it be proved that the sul-
phurets, when collected in a clean concentrate free
of sand—as they can easily be—do not assay enough,
to leave a profit on further and more expensive
treatment, or on shipment to smelters, it is useless

to add concentrators to the copper plates. The sulphurets in this case either run to waste or are roughly saved by crude and cheap concentrating appliances for some rough treatment like raw panning, which will yield a trifle over cost of operation.

As a general rule it can be said that if the percentage of sulphurets does not exceed 10, it is better to stamp fine enough for copper plates and Frue vanners at once, for simplicity and economy; but when the percentage runs much above this, a coarser crushing and use of jigs will be advisable; the relative advantage of the two processes will be more fully treated of in the article on concentration of ores, as well as of a combination process by which stamping with coarse screens and treatment by both jigs and vanners is advisable. Most gold ores, even when heavily sulphuretted, will not stand a very coarse crushing and jigging, unless the coarser jig tailings are re-ground, because the rock particles still contain too much gold. In such cases expediency is the only guide in the choice between compound treatment and the probable increase of loss by sliming when stamped fine enough at one operation, and it will be shown later how this last danger can be reduced, by proper care, to a point lower than is usually supposed.

The concentrations produced require of course a special treatment; and this will come under the

next head of Non-concentrating Ores, which are already concentrated by Nature. It may be mentioned, however, that there is no excuse for producing unclean concentrates with modern machinery; and it is clearly advisable that a material which is to be treated by a more expensive process should be as highly concentrated as possible, free from valueless rock as nearly as may be. In California it is not unusual for a contractor to put in concentrators under agreement that they will save 90 per cent. of the mineral freed by crushing from the gangue, and produce concentrates not containing over 10 per cent. of sand. In a properly running mill under good management the concentrates are delivered almost clean, say 3 to 5 per cent. of sand; although there are some partially oxidised ores in which an iron sand of intermediate specific gravity between mineral and rock is allowed to pass over with the former, on account of its gold value.

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(2) NON-CONCENTRATING SULPHURETTED ORE.

The concentrates obtained in a mill will be included with the heavily sulphuretted ores selected from the mine under this one head; the only difference being that one is already crushed and the other is not. To bring both classes to the same condition, reference will first be made to crushing the crude ore. This is best done by rolls, and dry, as

a preparation for roasting. The modern designs of crushing rolls differ materially from the old Cornish rolls. They are now constructed of compact form on a low bed-plate, driven independently by belt pulleys without the use of gear wheels, and at a speed of 100 to 150 revolutions per minute; while the shells are made of forged steel when fine crushing is necessary, so that the faces can be turned up occasionally and kept true, which is an essential for large capacity. The degree of fineness to which crushing must be carried depends on subsequent treatment : for smelting, it is unnecessary to crush finer than will secure the necessary elimination of sulphur in the first roasting; for chlorination, fine crushing is required, both to secu. the dead roast and insure the solution of the gold. There are some ball and roller grinding mills which may be used for the crushing of the rich ore, because usually small quantities only are involved, and strict economy is not important; so that, while such mills are by no means adapted to superseding stamps, as their inventors claim, they have a limited sphere of usefulness for grinding small quantities, and for this special purpose they have their advantages of simplicity over crushers, rolls, and screens combined in a plant. Where the grinder does not have a fixed screen so as to deliver at once a sized product, as, for instance, with rolls, it is necessary to screen outside and return the coarse to the

grinder.   Usually this is done by revolving screens
of circular or hexagonal section; but of late a
separator which is very simple and effective, using
currents of air for the sizing, has been used with
success.   This classifier is known as Mumfo hird and
Moodie's separator, and is used, both in England
and the United States, in connection with Buhr
millstones, rolls, and centrifugal mills.   An effective
machine of this character has the advantage over
screens of less wear and tear, and less interruption
to work from breaking of wire cloth and discharge
of coarse pieces.

The processes which can be used on the class of
ore now under consideration will be the following:—

(1) Chlorination.
(2) Smelting.
(3) Amalgamation.

It is not worth while considering the claims of
chemical and other processes for extracting the
gold, as these notes are intended to cover simply
what is known and proved, not what is claimed or
in process of being proved.

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(1) CHLORINATION.

A good deal has been written of late on this
subject, and it has been the basis of several new
processes which depend for their success on modi-
fications of procedure and the production of

essential element, the chlorine. The general points of the process have already been treated of under the head (A) Free Ores, so that it is unnecessary to dwell longer on this subject. In most mining camps it is the process most likely to be adopted on concentrates and hand-picked sulphuretted ores. When silver is present in quantity to justify the extra treatment, a double leaching is employed. The ore is roasted nearly " dead," then a small percentage of salt is added, and the silver is chloridised, the sulphur is all driven off, and the ferrous and cuprous sulphates are oxidised. The ore is then "gassed" as usual, with chlorine, and the gold leached out. The residue is again leached with hyposulphite solution, to dissolve the chloride of silver, which is precipitated as sulphide.

(2) SMELTING.

The smelting process, either completely or partially carried out, offers an alternative to the chlorination process which has not been sufficiently considered by millmen hitherto, probably because it is a distinct business in itself, and its capabilities only appreciated by educated metallurgists; but at the present day the services of good smelters are so easily obtainable that there is no reason why this branch of reduction should be neglected where conditions make it available, for chlorination

requires equally a special experience of the man
in charge of this department. The applications
of the smelting process to gold ores are covered
by the following modifications, to be separately
described :—

(*a*) Complete smelting to silver-lead bullion.

(*b*) Concentrating smelting to iron matte.

(*c*) Concentrating smelting to copper matte.

Practically these modifications are simply deter-
mined by the character of the ores, and differ more
in products than in operation, but it will be clearer
to treat them as distinct.

(*a*) Lead Smelting.

This is an operation which can only be economi-
cally carried on under very favourable conditions
of lead ore supply, fuel, and transportation at
reasonable rates for the base bullion ; and therefore
would be available only where smelting as a distinct
operation is profitable, regardless of the special gold
ores under consideration. It is possible however,
under certain circumstances, to employ this opera-
tion to a limited extent even at a comparatively
high cost, where some little lead ore is available.
In such cases the concentrates and richer sul-
phuretted ores are roasted, and mixed with lead
ores, fluxes, and litharge of previous runs, smelted
to lead bullion which is cupelled to gold and silver

bullion, and the litharge used over again for the smelting. This process properly conducted, though expensive in appearance, may be made available on rich ores and concentrates, and will yield a very high percentage of the value. Where wood is abundant this is used for the roasting, and charcoal is made for the smelting. With excessive charges for transportation, and rich material to work on in small quantity, and a supply of lead to make up losses at a not excessive cost, the intermittent lead smelting is practicable.

(*b*) SMELTING TO IRON MATTE.

This operation consists in partially roasting the rich ores and concentrates, and smelting with the necessary fluxes for a fluid slag, with the production of a rich iron matte containing all the gold and silver, and some lead and copper if sulphides of these metals exist in the ores. The operation is simple, and with cheap fuel is reasonable in cost. As the roasted material will consist largely of oxide of iron, and usually contains quartz in greater or less quantity, the fluxing is not generally a difficult matter. The disposal of the enriched matte must depend on circumstances. Frequently it can be run up to so valuable a grade as to justify shipment, even at high rates, to large smelting works for reduction ; or it can be crushed, roasted, and

chlorinated. Wood and charcoal can be used as
fuels. The roasting in some cases can be done
in open piles sufficiently for the coarse selected ore
of the mine, while the concentrates are worked in
reverberatory furnaces, both being smelted to-
gether in a stack furnace for the matte production.
Of course, the use of this process as a mere pre-
liminary to chlorination can only be justified where
its cost is less than that of the latter; and there
are mining districts where chlorination on a large
scale must be too expensive on the crude ore, but
would be justifiable on a few tons daily of very rich
material.

(c) SMELTING TO COPPER MATTE.

This is precisely the same as the smelting just
described for iron matte, except that the presence
of copper gives a distinctive character to the pro-
duct, and may add to its commercial value. Both
in this and the preceding process, the matte can
be enriched still further by a second partial roast-
ing and smelting, which in the case of copper-
bearing ores has the advantage of increasing the
copper contents as well as the gold value of the
product. In many cases the copper may help to
pay or wholly pay the cost of transportation and
refining of the matte.

It is not necessary to go into details of the smelting operation, which is fully described in various text-books; the only point under consideration now is its practicable application to gold ores. There is as great a difference between the cheapest and most costly working by the chlorination process in the United States, as there is variation of smelting costs per ton—viz. from 18*s.* to 80*s.* per ton of 2000 lbs.—but of course the quantities handled in the cheapest working smelting plants are larger than those worked in any chlorination establishments.

The advantages of the smelting processes are as follows:—If silver or copper be present it can be utilised without extra expense or change in the process; the plant is simple and can be started very crudely and economically in furnaces built on the ground for experimental results; and the process is based on an exact science. It is not necessary to experiment as to the condition of the gold in the ore, an analysis of an average sample would enable an educated smelter to state exactly what could be done with it, and what fluxes would be useful in its reduction; the items of fuel supply, labour, and transportation, would enable an estimate to be made of the cost.

(3) AMALGAMATION.

The sulphuretted ores and concentrates can, as
a safe general rule, be considered as not adapted to
amalgamation without a previous roasting. In some
few cases, where the gold is comparatively coarse,
a sufficient proportion of it can be extracted by
raw pan amalgamation to pay a profit on the
operation, and this process is used at places in the
Australian Colonies, usually after a crude process
of concentration, which itself involves considerable
loss of fine material and the production of unclean
concentrates; and in some few cases, the, value
thus extracted is to an appreciable extent, in the
form of amalgam, lost before concentration. Gene-
rally speaking, therefore, it is safe to say that raw
amalgamation is unadvisable on the material now
treated of.

The dead roasting of sulphurets as a preparation
for pan amalgamation, simplifies and improves the
process, by preventing the loss of quicksilver con-
sequent on working raw sulphides, and increasing
the percentage of gold saved; but it is not so
successful as is generally supposed, or as theory
would promise. The operation of roasting- while
it apparently frees the gold from its combinations,
increases perhaps the size of the gold particles, and
eliminates the objectionable sulphur compounds rea-
dily

seems to have a bad effect on a large part of the gold, putting it, superficially at least, in a condition very unfavourable for securing contact with quicksilver. The extent to which the gold is thus affected varies curiously in different ores of apparently similar composition; and the conditions of roasting have also an influence on the result. For the amalgamation itself of the roasted ores various methods are recommended. One process used in the colonies is by working with large excess of quicksilver and little water, and apart from contact with iron. The effect of grinding in iron pans seems in some cases much less beneficial than when amalgamation is conducted in stone arastras. The use of gold amalgam in place of quicksilver, and the avoiding of contact with iron surfaces, was found most beneficial in experiments conducted by Stetefeldt in Mexico, and a high percentage was extracted from a low grade ore. On the other hand, experiments on many gold ores in the New York Ore Testing Works gave unsatisfactory results by all these processes after roasting in a small reverberatory furnace, and nothing but chlorination was found effective when the material was rich in gold. On pages 25 and 87 reference is also made to this subject of roasting gold ores.

On any given ore, experiment alone will show

how high a percentage may be extracted, and the
best conditions of heat and time in the roasting;
but it would probably be fair to say that on
material assaying above 2 oz. gold to the ton, this
process is seldom advisable; and even below this
value the practicability of chlorination or concen-
trating smelting should be first considered.

(C) Exceptional Ores.

There are occasionally met with ores of gold in
which the gold is not free so far as tests indicate,
and yet there are no sulphurets present. These
ores are usually oxidised in character, changed
from their original form, and contain chloride of
silver in addition to the gold. Some of these ores,
when leached with hyposulphite of soda, yield a
large portion of the gold as well as the silver to
solution; and this fact would indicate that the gold
exists as a chloride, either combined with the silver
as a double insoluble chloride, or mechanically
protected by the latter from leaching out by
natural water drainage in the mine. Such ores are
uncommon, but have been worked to some extent
in the United States by leaching raw ore with
hyposulphite of soda, and then concentrating
for the fine carbonate of lead also present, and
its combined silver. Concentration and pan

amalgamation would probably be effective on such ores.

The presence of tellurium in gold ores sometimes complicates the question of treatment. If in small quantities in the presence of sulphurets, it must be considered as part of these in the general plan of treatment. If the value of the ore lies mostly in tellurides of gold and silver, with little or no sulphurets present, the most successful method yet found is by selection of the rich ore, and concentration with peculiar care, and double treatment, of the low grade ores. Both rich ore and concentrates are then so valuable that a perfect smelting process, or shipment to smelters, is advisable.

If to the above two classes of exceptional ore is added the class described under (A) Free ores, it will be pretty safe to say that the remaining gold ores of the world so far as yet worked do not justify the use of the terms "rusty" and "float" gold as commonly employed, but that these are simply picturesque titles for necessary loss, imagined loss, or avoidable loss. The term "float" gold is especially misleading, and "fine gold in suspension" would in all cases be more correctly descriptive; a very large piece of gold, if dry, will "float" on the water, and a microscopically small piece wet, will sink. It is not too comprehensive to say,

considering the very few cases in which the term
" rusty" gold is really justified, that the more a
millman uses the two terms " float" and " rusty,"
the less experience and skill will he be found to
possess.

CONCENTRATION

OF

GOLD AND SILVER ORES.

PART II.

———•———

THE credit of systematic and scientific concentra-
tion of ores is, unquestionably, due to the Germans;
but as the working of gold and silver ores without
regard to saving of baser metals is practised in
Germany to a very limited degree, and that too in
a developed country with cheap labour, fuel, and
transportation, it follows that German practice is
without authority in this branch; while circum-
stances, and a great variety in ores, have made the
United States the natural nursery of this class of
work. The following advances over German
methods may be noted in the United States. (1)
Direct coarse stamping and classifying over jigs and
slime machinery. (2) Direct fine stamping over
improved slime-working machinery without sizing.
It is not necessary to consider the essentially En-
glish methods of concentration as still existing in
Cornwall: for, ill-adapted as they are even for good
work on tin and copper ores, they are much worse,

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and in fact quite out of the question, on valuable
ores of gold and silver ; and no one of any broad
experience ventures to defend the system of handling
and re-handling, with consequent production of
ill-defined " heads," " middles," and " tails," of the
fixed buddles, strakes, and frames still employed.

On lead and zinc ores, the essentially German
system of concentration is employed in the United
States, i.e. rolls, sizing screens, jigs, and slime
machinery.   On Lake Superior a special process
has grown up, from the character of the native
copper ores and conditions of the country.   Steam
stamps of a capacity of 200 to 250 tons daily each,
hydraulic classifiers, jigs of a somewhat improved
type, and revolving buddles, constitute the ma-
chinery employed.   The process has been criticised a
good deal by concentration men bred upon German
science, and charges of excessive sliming of the copper
and imperfect sizing for the jigs, have been made
against the system.   But there can be no reasonable
doubt that the copper men have selected a type of
plant which yields them more profit than any other
would ; and mining is a business carried on more
for the sake of profit than for the advancement of
science.

It has been assumed until quite lately that the
apparently unscientific process of steam stamping
for concentration, though proved commercially
successful on native copper, would stop there ; but

the enterprise of the Anaconda Copper Company, of Montana, has again changed the basis of calculation. This company had an immense plant of crushing rolls, sizing screens, jigs, and buddles, for working its sulphide of copper ores, and with a capacity of 1000 tons per day. The wear of rolls and sizing screens, and complicated nature of the whole plant, led to experiments by the Lake Superior system; and the financial results were so good that an entirely new plant, based on the steam stamp system, was built, and now has a capacity of some 2000 tons per day. Further than this, a steam stamp was put in for crushing silver ores at the same works for pan amalgamation, and another steam-stamp was erected in the Black Hills for working gold ores, and both of these are claimed to yield good commercial results. Curiously enough, the departure of the Anaconda Company from German systems was made under the direction of a German engineer, Mr. Stallman, of long experience in the United States.

In part explanation of the reason for the improved commercial results of the process, Mr. Stallman states that while the stamp does make a greater percentage of slimes than careful crushing by rolls, the difference is very largely made up in the great attrition of mineral which takes place in revolving screens, launders, and the elevating and returning of material for the rolls. The stamp delivers through

a screen, so that a sized product is immediately obtained ; and all the wear of revolving screens and elevators is saved.   There is also a quicker and more immediate delivery by launders to the concentrating machines than by the roll system, and attrition of mineral is diminished from this cause. Mr. Stallman states also that the steam stamp, by its rapid and enormous delivery, makes less slimes than gravitation stamps, as proved in crushing both ways on the same ore for pan amalgamation. In Australia, steam stamps have been erected for silver-lead ores, and the Lake Superior system adopted in full.

In the last few years the concentration of gold and silver ores by a direct process, without sizing, after fine crushing by stamps, has become the established process for a very large variety of ores in the United States, and when properly conducted is as perfect as any mechanical process can be.   The following notes, based on many years' experience in the United States, and on several years' experience in testing-works treatment of ores from all parts of the world, are intended as suggestions for special cases, and are warranted by results obtained in practice in the directions indicated.

As reference will be made to settling boxes and hydraulic sizers, which are outside the experience of many millmen, some description will be first given of their construction and use.

SETTLING BOXES.

These are for the purpose of settling the sand and mineral in suspension in a flowing current, so as to run off the excess of water not needed in subsequent treatment of the ore, and to deliver continuously a thicker pulp from the bottom of the pointed box. The regular settling tanks, used in silver mills before pans, and for retaining tailings in some places, are well enough known ; but these require digging out, and changes of the pulp flow from one to another ; they are therefore useless for the purposes of a continuous working process. Where tailings are caught in large pits, it is frequently seen that the settling is not so perfect as the large size employed would warrant, and this is due to the surface currents, and channels cut in the deposited material when it fills to the surface. The large pointed boxes, if properly built, are deserving of more attention than they have yet received, for many purposes. Where water has to be used in part over again in a mill, a series of these boxes will do far more effective work than pits or settling tanks, and require no attention or labour ; they will deliver a small stream of thick concentrated pulp at the bottom, and give an overflow of almost clear water at the top.

To make them effective, however, there are

several points which must not be ignored, these
are :—

(1) Proper angle at bottom to insure descent of
slimes—not less than 50° from horizontal.

(2) Proportioning of water inflow to capacity.

(3) Avoiding too small a discharge opening at
the bottom.

(4) Preventing surface currents from the inflow
to the overflow end.

(5) Preventing ingress of coarse sand, chips,
and other obstructing matter.

On Plate II. will be found complete details and
dimensions of a large pointed box, which is of
sufficient size to handle the pulp and water
from 5 or 10 stamps, according to circumstances.
It will be noticed that a partition extends across
the box near the inflow end, dipping well down
into the water, so as to cut off surface currents
and insure a mixture of the incoming pulp with
the whole mass of water in the box; in the
absence of this, currents of muddy water will be
seen flowing through the clearer mass direct to the
overflow end. A frequent mistake of millmen in
making flat settling tanks is to assume that length
is all-important in settling slime, and to put in
too many zig-zag partitions, so as to force the water
currents to take as long a course as possible. This
frequently destroys the very advantages sought,
by making a comparatively rapid surface current

in narrow channels. If slime will remain in sus-
pension in a given current of water for 12 feet, it
will do so nearly as perfectly for 50 or 100 feet. The
proper means to insure settling is to diminish the
speed of current, not to lengthen its course. For
example, to put the combined pulp from 10 stamps
over two of the pointed boxes shown in Plate II.
placed one after the other, would be nothing like
so effective as dividing the pulp and putting the
product of each 5 stamps over a separate box. To
put zig-zag partitions across the settling box, would
be to lessen its efficiency for perfect settling, by
determining relatively rapid currents in fixed
directions, instead of producing an incorporation
of the incoming pulp with the mass of water, and
the consequent overflow at the distant quiet end by
mere rise of level.

The capacity of the box shown will depend, of
course, on the perfection to which settling has to
be carried. For concentration, it is by no means
essential that the overflow should be clear water,
because any mineral which will not settle in a
reasonable time in still water, will be small in
quantity, and only very partially saved by con-
centration in any case. Where, however, it is a
matter of settling for pan amalgamation, the
greatest care is necessary, because the chlorides and
sulphides of silver are apt to be exceedingly light
and flakey in form.

tion after amalgamation is always imperfect as com-
pared with the same before pans.

The discharge at the bottom of the pointed box
must be regulated in size by reference to the quan-
tity received and thickness of pulp needed. With a
large box, as shown, and consequent high head of
water pressure, a syphon discharge must be used;
otherwise a very small opening, liable to frequent
choking, would be necessary. A convenient dis-
charge is that shown in Plate II.; a short nipple of
1½-inch pipe, with a tee of the same, and an upright
pipe about 3½ feet in length, to the upper end of
which a 2½-foot length of 2-inch hose is attached,
with a sliding gate-tap at the end, similar to what is
known as a molasses tap; or the hose can be fitted
into a small square box with an opening covered by a
sliding gate in front.   The advantage of the rubber
hose is, that by raising or lowering the discharge
end, the pressure from head of water can be regulated.
Usually 2 feet to 3 feet difference in level will insure
good discharge. The reason for a tee in place of
an elbow at the lower end of the pipe is to allow
of emptying the tank when inflow ceases, so as to
prevent the box from packing solid when the level
of discharge is reached; also to allow of removing
obstructions to flow; and also to keep an opening
for continuous discharge while the box is first being
filled, until the water-level reaches the top, when
the syphon tap can be opened.   The end of the

An examination of the settling tanks in
er mills shows clearly that the operation is
fect as to make it dangerous to change
m, and the large boxes described will
give as clean an overflow with much
f labour. With a proper distribution of
a number of boxes—not the whole pulp
a series of them—very close work can be
t the Montana Mine, 10 boxes, of the size
on Plate II., were put in by the writers, and
the settler discharge from 50 stamps hand-
tons of ore daily, together with the great ex-
water resulting from amalgamation, and these
ellent work with almost clear water outflow.
stem was adopted as a preparation for concen-
; but owing to the irregular settler discharge
rnations of rushes of pulp and then little or
ow—and also to the proved advantages of con-
ation before amalgamation, the works were
changed and the pulp delivered direct from
os to the vanners. Enough however was ac-
lished to prove the complete efficiency of the
es, and to justify the conclusion that, with
per arrangements, a great improvement could be
cted over the tank system of settling for pans.
working out the details for a mill not using
continuous process, the storage of the con-
ious flow of thickened pulp between charges
pans would have to be considered, and might

of discharge opening in the bottom, a light chain can be attached by a staple to the inside end of the wooden plug used in the discharge tee. The chain passes through the nipple in the bottom of the box, and up to the top of the latter, where it is fastened, to prevent it from dropping back, and with suffi- cient slack to allow of the wooden plug being with- drawn about a foot. By working the chain up and down, any obstruction is cleared, and the flow again started.

To start the box in operation, the wooden plug is first removed from the tee below, which is either left open or a half-plug put in to diminish the discharge and shorten the time of filling. The pulp is then turned in, and as soon as the box is full and overflow begins, the tee is plugged up and regular discharge begins by the syphon tap. Or the box can be filled first with clear water, both discharges being closed, and the syphon tap opened as soon as the pulp is turned in above. In case the pulp flow ceases, from stoppage of stamps or other cause, clear water is at once turned in to the box to supply its place, until all the sand and slime is delivered from the box; or, if loss of pulp is not important, and water scarce, the plug is removed from below and the box emptied. Failing one of these precautions, the box will pack solid with sand, and give much trouble to clear and start again. The running in of clear water is most to be recommended,

because it insures the box being kept wet, so preventing any leaking; and, further, no delay occurs in again starting work by the necessity of filling the box before closing the tee.

The uses of the pointed settling boxes can be described generally as one of two operations.

(*a*) For the purpose of obtaining a clear overflow of water to be used over again where that article is scarce: the advantages over square tanks or pits being that the labour of digging out and loss by evaporation are avoided, while space is economised.

(*b*) For running off the excess of water introduced into a pulp—by crushing, sizing, amalgamation, or concentration—so as to produce a thickened pulp for concentration, amalgamation, drying for subsequent treatment, or storage as in the case of concentrates.

HYDRAULIC CLASSIFIERS.

It is well known that if a stream of unsized pulp be made to flow through a small pointed box with a smaller discharge at the bottom than the inflow, a certain concentration occurs, the lower discharge containing more coarse sand and heavy mineral than the overflow portion. Such a separation is, however, very imperfect, because the lower discharge must contain the slimes and muddy water which constitute the transporting current for the heavier

particles. The object of the hydraulic classifier is
to substitute a stream of clear water for the muddy
current, and thereby force all the slimes to ac-
company the overflow. The most perfect way of
accomplishing this on fine material is by making
the clear water pipe itself, under a fixed head, the
conduit for the coarse material. On Plate III.
will be found descriptions of this apparatus, the
dimensions of which can be varied in accordance
with the size of largest particles of pulp, increasing
the area as the material becomes finer and more
difficult to settle. The operation is based on the
end discharge of the water-pipe being less than the
quantity of clear water admitted by the valve, and,
as a consequence, there being an upward current
of clear water into the settling box.   Under this
condition, no muddy water can discharge below,
but only the particles of ore which have weight
enough to drop through the ascending current and
into the pipe.   By a simple regulation of the valve
and its resulting volume of upward current in the
box, all variations can be attained, from a clear water
discharge accompanied by a few of the heaviest
particles of the pulp, to a muddy water containing
the large bulk of all the heavy particles.   The
sliding partition assists the settling, by forcing the
pulp to take a downward turn, and so prevents
a rapid surface current across the box to the over-
flow. The clear water must be delivered under

fixed head, to insure uniformity; and this head
hould be low—very little above the water-level in
ıe classifier—because a high pressure necessitates
very small discharge orifice for the coarse, with
onsequent liability to choking, or a great excess of
ıater in the discharge.

On Lake Superior, the pulp flows direct from
he coarse screens of the steam stamp through a
eries of double V-trough classifiers, carrying the
ıulp in the inner one, and clear water in the outer,
ıith openings at intervals between the two, so that
he coarse particles drop first into the clear water-
rough, and thence, by stops and openings, are
lischarged to the different jigs. The system is
ıasteful of water, and less perfect in results and
onvenience of control, than separate boxes with
ıdependent water-pipe supply. On Plate III.,
'ig. 2, the arrangement of this separator is shown.

The trough classifier shown on Plate III., Fig.
, is a great improvement on the Lake Superior
ouble V-trough separators, and was first suggested
y Professor Richards, of Boston, and perfected by
/Ir. Coggin, of the Calumet and Hecla Mill. It
ıill be seen that this trough contains a succession
f depressions or boxes, and the clear water is intro-
ıuced by pipes which have no connection with the
lischarge openings, but have their delivery ends
lirectly in front of the latter. The valve of the clear
ıater-pipe is opened until more water is delivered

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than the opening in the box will discharge, and
in this way an upward current of clear water
is caused in the box full of flowing pulp. The
action of this classifier can be easily understood
from the drawing and previous description. From
each opening in a succession of boxes, with proper
clear-water regulation, a descending series of sizes
of ore particles can be obtained for the
jigs. In each box a short partition is a ac
prevent the pulp rushing through pulp, inc
current; and also a small shield is p er an
tally above the delivery end of the cl based
so as to break the upward current, less th
more general mixture with the mass he valv
box. This is patented, and is known ward c
met" separator. It has been found Und
that 72 of this style are now in use in arge
and Hecla Mill, handling 3000 tons o ave w
and with marked improvements in resu curren
old style trough separators they hav of th
One of the separators of the size sho urren
50 to 60 tons daily of the Calumet or n a cle ar
crushing by the steam stamps, deliver f the he
product to the jigs and using 700 to ter c nta
of clear water per ton of ore. To ad articles.
some experimenting in the distance by forcing
end of inlet pipe and the discharg so preve
stuffing box is first used, which ca ox to the
later for a fixed elbow on the inlet pi delivered u

The discharge from one of these separators in
the Calumet Mill is approximately as follows:—

From No. 1 spigot ($\frac{3}{4}$ inch) 20 tons coarse—heavy.
    „   2   „   ($\frac{1}{2}$ „) 12 „ coarse—light.
    „   3   „   ($\frac{1}{3}$ „) 8 „ medium.
    „   4   „   ($\frac{1}{4}$ „) 5 „ fine.
Overflow to buddles .. 15 „ slimes.

        Total   ..   .. 60 tons per 24 hours.

SHAKING AND REVOLVING SCREENS.

The revolving screen is more generally used than
a flat shaking screen, although the latter offers
some advantages in simplicity and cheapness.
For the purposes of concentration, sizing in
screens is generally conducted wet, and spraying
jets of water are used inside or outside the revolving
screens. The screens are sometimes cylindrical,
with shafts inclined to the necessary angle, or they
are built of conical form on a horizontal shaft.
The coverings of screens vary in different countries,
and according to size and character of the material
treated. The coarser screens are usually of punched
steel or iron, occasionally of sheet copper; the finer
sizes are of iron or brass wire cloth. The usual
practice in concentration mills, where coarse crushing
and jigs are necessary, is to employ screens only
above 8 or 12 mesh, and below this to use
hydraulic classifiers; but in some cases where

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intimate mixture of two minerals—say galena and zinc blende—necessitates close jig work and perfect separation, revolving screens as fine as 40 and even 60 mesh brass-wire cloth have been successfully run, and excellent work accomplished on fast running jigs down to this size.

The wear of screens and delay incidental to changes of the covering on breakage, and the almost necessary employment of elevators to get the requisite fall in a mill, make it decidedly preferable to use hydraulic classifiers as far as possible in place of screens. The separation into equal sizes by a revolving screen, is more desirable for subsequent jig work than the classification into equal falling particles effected by a hydraulic separator, if the minerals to be separated do not vary much in specific gravity; and for this reason, the character of the material and closeness of jig-work necessary, will regulate the extent to which one can replace the other system of preparation. Less water is necessary in jigs working the discharge of a hydraulic separator than if working from a revolving screen, owing to the greater uniformity in the sizes of the particles from the latter.

METHODS OF CONCENTRATION.

THE different methods of concentration can be classed roughly in two divisions for facility of description, viz :—

(*a*) Coarse crushing, and subdivision of treatment between two or more kinds of concentrators.

(*b*) Fine crushing, and direct treatment of the whole resulting pulp by one kind of concentrator.

As a general rule the ores of gold and silver come under class (*b*) of fine crushing; but as there are ores of copper, lead, zinc, antimony, and massive iron pyrites, in which the gold or silver contents are of equal or more importance than the base metals, it is necessary to consider both classes of work.

(*a*) COARSE CRUSHING.

The base metals—ores of lead, zinc, copper, antimony, and iron usually carry the heavy minerals in massive form of bunches, pockets, stringers, and seams through the waste rock; and, almost necessarily, in pretty large percentage in order to justify working. Where the base minerals carry gold and silver in profitable quantity lower percentages are workable, and frequently finer crushing

must be resorted to in consequence. The treat-
ment of this class of ores will be either by rolls,
screens, jigs, and slime tables, or after the American
practice of coarse stamping, hydraulic sizing, jigs,
and slime tables. Both processes have been fre-
quently described, and there is no necessity for
going into detailed description here. The selection
of the slime-dressing machinery depends largely on
the quantity of gold and silver present, which gene-
rally varies in inverse proportion to the percentage
of heavy mineral in the ore. For working large
quantities daily of a low grade ore, valuable chiefly
or wholly for the baser metals, the usual custom is
to use revolving buddles, either single or double-
decked. Where the percentage of mineral is less,
and its value in precious metals higher, closer work
is profitable on the slimes, and Frue vanners are
employed in addition to the jigs. The advantages
of the revolving buddles consist in low first cost,
large capacity, and ability to stand large quantity
of water, which is always present in the pulp after
the various operations of screening and hydraulic
separation. The disadvantages of the buddles as
compared with vanners are, that they make no
sharp line of separation between heads and tails,
but produce a middling product, which must be
re-concentrated ; the operation also involves greater
loss of fine mineral ; and, further, the material must
be carefully sized by hydraulic separators to get

the best results, which is not necessary with the vanner.

When the Frue vanner was first introduced, it was assumed that sizing of the material would be as beneficial as in other slime-dressing machines, like revolving buddles, Rittinger tables, and end-bump tables; and the first pamphlets published describing the use of the machine made mention of the fact. Actual practice, however, soon determined that in almost every case, taking a product of 40-mesh crushing, better results were obtained by simply evenly dividing the pulp over two machines, than by making a separation by sizes into two portions treated separately. Without going into the theory of particles of matter of various sizes and specific gravities in a moving current of water, the following illustration will be the best explanation of an apparent anomaly. In any concentrator but a shaking belt, if a flat heavy object—say a sixpence —be thrown among the pulp that is being worked, it will appear immediately with the concentrates or headings; its comparatively great weight, and small surface edgeways exposed to the water current, insure its immediate recovery. If, on the other hand, the same coin is put on a Frue vanner while in operation, it will not pass over with the fine mineral steadily delivered past the water jets. The shaking motion, by cutting away the supporting adhesion of the belt surface, owing to the inertia of the coin,

allows the light current of water on the edge of the
coin to wash it backwards with the sand. The
same action applies to coarse particles of sand
mixed with fine particles of mineral; the latter
adhere strongly to the belt, and are unmoved by
the water current; while the inertia of the larger
particles prevents adhesion to the rapidly shaking
surface below them. Specific gravity of course
also comes into play, as between two equal sized
particles: but the effect of mere mass is such that
the Frue vanner with smooth belt is not adapted to
saving coarse mineral; an excess of wash water at
the head drives down the coarser mineral, while the
finest clings to the belts and safely passes the water
jets. The introduction of the improved riffled
surface belts on the vanners enables a coarser grade
of ore to be worked, in larger quantity, and with
greater inclination and increased supply of water.
For the regular smooth belt machine, a screen of
40-mesh (1600 holes to square inch) is the usual
limit for good work; coarser than this the work
done is not so effective, and plenty of simpler
machines are just as good for the coarser particles
when sized. No mineral is too fine for the smooth
belt vanner, it is essentially a slime machine,
adapted to the very finest slimes, either alone or in
mixture with coarser sand, as represented by the
pulp from stamps using a 40-mesh screen. Of
course perfect saving with any automatic machine

is out of the question, and in speaking of the
saving effected the terms must be received as
merely relative. The subject of closer saving than
is possible by a single treatment will be touched on
later. In taking the ordinary work done in gold
and silver mills, it must be remembered that the
ore is simply stamped direct over a single machine
and allowed to run to waste, and this simple process
gives clean concentrates, and usually from 80 to 90
per cent. of the total heavy mineral—a percentage
which can be increased, if the material justifies it, by
a second treatment. In some cases the loss of silver
and gold is greater proportionally than the per-
centage of loss of the heavy mineral: the precious
metals running more with the specially brittle
minerals, or the more finely divided ones; and
although, theoretically, excellent concentration may
be done according to percentage of mineral saved,
the loss of gold or silver is really much larger
than is indicated by the mineral recovered. In
such cases it is of great importance to continue the
operation, as a very slight increased saving of
mineral may mean a largely increased recovery of
the important metals.

The advantages to be derived by steam stamping
and hydraulic sizing, as compared with the use of
rolls and screens, have already been touched on.
Steam stamps make less slimes than gravitation
stamps. A heavy blow is struck, but the crushed

reason, and others to be mentioned, the improved riffled belt vanner is to be preferred for such mills as treat large quantities of slimes. The improved belt will stand twice the quantity of water and pulp that an ordinary vanner will; and where used in mills to take the direct product of gravitation stamps, one is placed to each five stamps instead of two of the ordinary belts required for close work; in fact, on certain ores, one of the improved belts has been used for ten stamps. The new belt is placed steeper, shakes somewhat faster, and requires more water than the old belt. The riffled surface retains and carries up a larger proportion of sulphurets than the plain belt at the same speed of travel, so that it has its advantages on ores containing much sulphurets. In Nevada, experimental crushing by five stamps through a 24-mesh screen, direct on to one of the improved belts gave very fair results. Often the finer jig work done in mills is not very good, as fine mineral is delivered with the coarser sand from the hydraulic separators, and is partly lost in the jig tailings. In such cases the improved belt vanner seems to offer chances of increasing the yield. Late tests at Tuscarora, Nevada, point to this larger application of the machine, as one belt is doing better work than two fine jigs on the material as sized for the latter, and is treating up to 17 tons per day, with a saving of 85 per cent.

The various new concentrators which come
out yearly are usually modifications of existing
machines, pans, upward water currents, or shaking
tables.   For coarse mineral, nothing can be simpler,
cheaper, or more perfect than good jigs, where
proper sizing is adopted.   The usual idea of
the gold miner is that a gold pan represents
perfection of work in concentration, and various
machines crop up again and again with claims of
reproducing the action of a pan ; the fallacy of
this has been explained on page 9, and the failure
of the machines themselves is the best illustration
of the fallacy.

(*b*) FINE CRUSHING.

For the preparation of the ore requiring fine
crushing, say below 20-mesh screen, stamps are
almost universally used, except where of late the
Huntington roller mill has come into use.   The
various pulverisers which are advertised in the
markets, may have in some cases merits of their
own, but cannot be considered in this paper, which
deals simply with modifications in the application of
well-known and existing machinery.   The Hunt-
ington mill having been in steady use for several
years in California, alongside stamp mills, has
established its right to consideration in any article

on fine crushing. In California it has been proved
that this mill can be run continuously from year to
year with very moderate wear and tear, so much
so in fact on certain ores, that at the Spanish Mine,
an ore yielding less than one dwt. of gold per ton
has been worked to a profit, owing to peculiar
facilities for cheap quarrying rather than mining.
The advantages of the mill consist in its low cost
of freight to mines—being only one-third the
weight of equivalent stamping plant; its facility
of erection; and the small power required to run it.
As the mill uses screens to regulate its discharge,
it gives a product, like stamps, ready for immediate
treatment. The rapid rolling action of the crushing
faces is effective as a preparation for concentration,
and compares very favourably with stamps as to
the production of slimes. As in stamps, amalgam-
ation of free gold takes place inside the mill, and
outside on copper plates if these are used. For
crushing soft and fine ore, the mill has decided
advantages over stamps; and has therefore its
sphere of usefulness as a re-grinder, and for working
soft ores, in which applications stamps are very
unsatisfactory. An automatic feeder is used with
the mill, so that no extra labour is involved as
compared with stamps. On page 18 attention was
called to the advantages of re-grinding the coarser
tailings of some gold ores carrying fine gold. For
this the Huntington mill can be made effective

by proper regulation of speed, and has the advantage
of also securing the amalgamation at the same
time.

Of late, rolls have been advocated for fine crush-
ing, and where the operation has to be performed
dry and not very fine, in preparation for roasting
with leaching or chlorination, there are decidedly
advantages to be gained. For ores requiring wet
treatment, however—free gold and silver ores, and
concentrating ores—there is nothing but disadvan-
tage in rolls. Although there are various devices for
both concentrating and amalgamating dry pulp, it is
quite certain, from the failure of these processes in
practice, though known for many years, that where
water is obtainable, dry treatment is not worth con-
sidering. The mere item of drying the ore, and the
disadvantage of dust in dry crushing—even if the
processes be granted the full efficiency of equivalent
wet methods—are sufficient to prevent any serious
consideration of dry treatment, except as a matter
of necessity from the absence of water.   No one
desires to dry an ore, crush dry, and then wet it
again; and the fine crushing wet in rolls has
obvious objections against it. For dry crushing,
stamps are not nearly so effective as for wet
work; and, therefore, what would be a favourable
comparison for rolls in one case, becomes very
different in the other. Rolls require screening
and rescreening, with steady return of uncrushed

particles; and all this means excess of water intro-
duced, and the running of screens and elevators in
addition to the crushing machinery. Again, the sur-
faces of roller shells must be kept turned up true
to do effective work fine crushing, or their capacity
drops directly; while the capacity of stamps varies
very little with wear of castings, as increased drop
tends to neutralise decrease in weight. Some ores,
containing clay, will press into thin cakes by
the rolls, and become an increasing factor in the
returns from the screens.

From the above considerations it will not be
necessary to include, for the class of ore under con-
sideration, anything but stamps and Huntington
mills; the former for hard rock, the latter for softer
ores, and for re-grinding jig or stamp tailings. The
Heberle mill is used, both in Germany and the
United States, for re-grinding jig tailings. It con-
sists of two vertical steel plates, with roughened
faces, running rapidly, but at different speeds, in
the same direction. Its adoption in the United
States by the Anaconda Company shows that it has
merits of its own, one of these being the reasonable
proportion of slimes produced in its operation. The
wearing plates are made of various kinds of special
hard steel. As already pointed out at page 37,
various new pulverisers may have their utility in
grinding small quantities of material, and especially
where the same is already reduced in size—e. g.

jig or coarse stamp tailings—whereas the same machines are not worth considering at present on their claims of superseding stamps and rolls for the preliminary crushing of the crude ore.

Some attempts have been made lately to use steam stamps for fine crushing on gold and silver ores in Dakota and Montana, but there are natural difficulties in securing a free discharge and reasonable life of necessarily thin screens in such a process. A possible utilisation of the advantages of steam stamping would be in the comparatively coarse crushing of masses of low grade gold ore, with regrinding of the coarser particles of rock, if rich enough, as advocated on page 18. The advantage of the steam stamp in space, labour, and concentration of work, is evident; but its economy as to power is not established as compared with gravitation stamps for fine crushing. With the regular stamps more work is thrown on the rock breakers, but the power can be applied for the whole work in the form of a perfect steam engine as against the comparatively simple steam cylinder of the heavy stamp. The work of a really good modern stamp mill, with first-class compound condensing steam-engine, leaves very little room for improvement as to economy of fuel; and the advantage of subdivision of the work among a number of batteries is that stoppages for repairs and breakages only affect a small part of the crush-

ing capacity at the time.   Again, water power
is applicable to the regular stamps in a simple and
direct manner, insuring the fullest efficiency.   For
steam stamps it has been proposed by Mr. Stallman
to use water power to compress air for use in place
of steam; but this could not be done with a limited
water power, as being a much less direct application
of the force as compared with gravitation stamps
driven from a water-wheel.

In Montana it is stated, on a fair comparison
between both kinds of stamps, that the steam stamp
makes less slimes in fine crushing than the gravi-
tation stamps.   This would be a direct advantage in
concentration.   Figures are not at hand to illustrate
this or establish the matter of comparative cost.

A few words on some special propositions in fine
ore concentration may prove suggestive in getting
the highest results out of present methods and
machinery.

There are certain ores of silver and gold which
it is difficult at first to class in the proper system
of treatment; and the presence of one or both
of the precious metals, as well as the character
and quantity of base metal sulphides present,
will have an influence on the selection of the
machinery.

To cover the well-known ores of both metals for

which fine concentration is likely to be applicable, the following subdivisions can be assumed :—

(1) Gold ores with less than 20 per cent. of sulphurets, little or no silver.

(2) Combined gold and silver ores, with less than 20 per cent. of sulphurets.

(3) Silver ores with less than 20 per cent. of sulphurets.

(1) GOLD ORES.

As a rule, the ores of this class contain free gold in addition to that locked up in the sulphurets, and it is always best in such cases to use copper-plates in advance of concentration. Under the head of Gold Amalgamation these ores have already been described and their treatment suggested ; for such as contain finely divided, brittle, or rich sulphides and tellurides, the remarks on close and double concentration, to be made on the silver ore class, will be equally applicable.

(2) COMBINED GOLD AND SILVER ORES.

In this class come some of the most difficult ores to decide the treatment of, because a process adapted to the extraction of the gold may be very inefficient for recovery of the silver, and *vice versâ.* When the one metal is in small proportion as to

value, it is frequently sacrificed to the most profit-
able process commercially for the other metal.
For example, many of the base silver ores of the
United States contain from 5 to 15 dwts. of gold,
and from 20 to 50 oz. of silver, per ton. On these
ores the dry stamping, roasting, and pan amalgama-
tion, is mostly used; which will, under proper
conditions, extract 90 per cent. of the silver, but only
40 to 60 per cent. of the gold. The introduction
of the coarser crushing, instantaneous roasting by
Stetefeldt furnaces, and double leaching by the
Russell process, has of late come into prominence
on this kind of ore, and is giving excellent results
on some varieties, both as to economy, and the
extraction of both metals.

For either of the above processes, the ore must
necessarily be of a fairly high grade, and without
too high a percentage of gold in the total value.
When ores contain but little base metals, with high
proportion of gold value, the roasting process is
avoided if possible, and either copper plates and
concentration, or concentration and pan amalgama-
tion, is used. On this latter combination process
very little has been published, and its importance
will justify our giving a few details.

Pan amalgamation is effective chiefly on native
gold, native silver, chloride of silver, and simple
sulphide of silver. When the silver is in combina-
tion with sulphides, antimonides, arsenides, and

tellurides of the baser metals, the pan process becomes ineffective and expensive. By contact with iron surfaces, heat, and the addition of some chemicals—chiefly salt and sulphate of copper—a partial decomposition of the complex minerals is effected, and some of the silver amalgamated; but the wear of iron, loss of quicksilver, cost of power and chemicals, and the production of base bullion, together go far to neutralise the gain made in recovery of the silver. In such cases a great benefit is derived from combining concentration with amalgamation, for the two processes are applicable to different minerals. The light flocculent chlorides and sulphides of silver can be amalgamated to a high percentage, while concentration is almost useless on them in the form they exist in a free or decomposed ore. On the other hand, concentration can be made very effective on the undecomposed complex minerals, for which amalgamation is ill adapted.

There are two methods of combining the processes, according to their order, i.e. whether the pans are used first or the concentrators. In either case, the Boss continuous process of pan amalgamation is much more convenient and economical than the old settling tank and intermittent charge system. The former process, as is well known, consists in placing pans and settlers in a row on one level, connecting them all by short pipes, feeding

the pulp continuously into the first pan of the series, and allowing it to discharge continuously from the last settler. Its advantages consist in economy of space and labour, and the dispensing with the trouble of settling tanks; and, in connection with concentration after amalgamation, its great superiority lies in its continuous operation, as insuring a regular feed to the concentrators, which is all important, and almost impossible to obtain from the intermittent settler discharge of the old tank process. When concentrators are used before the pans, the tank system can be used, as well as if the stamps discharge direct to the tanks; but the continuous amalgamation of the tailings of the concentrators, if the Boss system be used, would simplify the adoption of the pointed box system of automatic settling, advocated at page 56.

In regard to the relative advantages of the two orders of succession, it may be briefly stated that concentration before amalgamation is the natural method, because it relieves the pans of the base minerals, which are a disadvantage in the amalgamation, and the subsequent concentration of which is made more difficult by the grinding or attrition of the minerals in the pans. The only argument against the universal adoption of this order rests on the disadvantage of sometimes having native metals (and some chlorides and sulphides) enter the concentrations, instead of appearing as bullion,

which they otherwise would do ; and also that very
perfect settling of the slimes from the concentra-
tion tailings is necessary to prevent loss of flakey
silver chlorides, and sulphides.   Where the free
metal is gold, the first-named disadvantage can be
overcome by using copper plates before the con-
centrators, and this process was adopted by the
Montana Company with great success, after first
trying pans before the concentrators.   The change
in the order of working by the Montana Company
has been productive of a considerable gross increase
in percentage extracted from the ore, a reduction
of one-half in the loss of quicksilver, and a saving
in the wear of pan-castings, fuel, and chemicals;
as well as the production of a higher grade of
bullion.   In this company's 50-stamp mill, the
tailings of the concentrators run into the usual
settling tanks because the Boss process is not
employed.

Comparing the combined process with dry-
crushing and roasting, the advantages of the former
consist in a reduction of cost of working, fully one
half that of dry crushing; a crushing capacity (
double for the same number of stamps ; a decrease
cost of erection ; and a higher saving of gold pres(
in the ore.   Against these advantages may
placed simply the increased percentage of si
extracted by the dry process when the ore is 1
A curious instance of successful roasting of a

and silver ore which is very free from base metals, exists in Idaho, at the Dickern Custer Mill. The ore treated is that of the Lucky Boy mine; it consists of a mixture of quartz and calc-spar, carrying free gold, native silver, brittle silver ore, and occasional minute crystals of iron and copper pyrites. The total quantity of base mineral present is so small, that merely dark blue seams and colorations break the general pure whiteness of the ore. This ore is crushed dry, roasted with 3 to 4 per cent. of salt in Bruckner furnaces at a low heat; with a resulting chloridisation of 50 per cent. of the silver, and a total extraction in the pans up to 90 per cent. of the silver and 80 to 85 per cent of the gold. An average proportion of the two metals present in the best ore treated is $1\frac{1}{2}$ oz. gold and 12 oz. silver per ton of 2000 lbs. It is probable that the unusual freedom from base mineral in this case accounts for the high extraction of gold after roasting. Although apparently so successful, it is questionable whether better commercial results would not follow from a change to wet crushing on this ore; because the cost of treatment is high, also a selection of the ore is necessary at the mine, and this increases the cost of mining, and involves loss of lower grade ore not workable by itself.

When combined gold and silver ores carry over 10 per cent. of base minerals, it usually happens that the silver does not exist equally through the

minerals present, but is concentrated in one of them as a rich brittle ore. It follows from this that concentration is often very ineffective on such ores; because, while 90 per cent. of the heavy base minerals may be saved in the concentrates, the loss of the fine silver-bearing mineral in the slimes may be fully 50 per cent. of the assay value of the crude ore. In some cases of a base ore, the clean concentrated heavy minerals do not assay more than the original ore from which they were separated.

From the above remarks it will be seen how important it is to determine, by actual tests on any given ore, the choice of dry or wet crushing, the adoption of concentration or otherwise, and the relative order of amalgamation and concentration when the combined process is decided on.

(3) Silver Ores.

The remarks already made as to ores of Class 2 apply equally in many cases where silver alone is present; so that it is unnecessary to repeat anything as to dry crushing, pan amalgamation, or the combined process of concentration and amalgamation; and the only points now to be described are those connected with special difficulties in concentration of silver-bearing minerals,

equally applicable to gold in the case of tellurides and rich sulphides.

Concentration is never absolutely perfect ; for, putting aside the loss of mineral particles attached to rock particles, it is always possible to show by hand-panning a loss of fine mineral in the tailings of a concentrator. The quantity of mineral so discovered determines the relative efficiency of the concentrator employed. Up to the present, no machine has given better results on finely-crushed ores carrying up to 20 per cent. base mineral, than the Frue vanner, and for this reason our remarks are confined to this machine for the special cases to be considered.

In working an ordinary gold ore containing under 10 per cent. of mineral, the proportion of fine mineral in the tailings will not exceed one-tenth of that present, if the concentrator is properly adjusted, not over crowded, and has regular feed and speed. On the large majority of gold ores a loss of one-tenth of the mineral present—after the free gold has been extracted by copper plates— represents so small a value that any closer concentration is not necessary. As an illustration, an ordinary ore may contain 10 dwts. of gold per ton, of which 6 dwts. are free gold, and 4 dwts. combined with sulphurets—i.e. combination in its broad sense, as described at page 33. A loss of one-

tenth of the sulphurets carrying 4 dwts., would make the tailings assay from this cause alone $\frac{4}{10}$ dwt. per ton, a value which would usually be ignored. It does not follow that this loss of mineral is entirely necessary, for a second concentration would reduce it, as will be shown.

DOUBLE CONCENTRATION.

THERE are ores, of both gold and silver, in which
the sulphurets are so rich that even a very small
loss by weight involves a large loss in assay of the
precious metals. Such minerals as tellurides of
gold and silver, ruby and brittle silver ore, come
under this head. In concentrating the tellurium
ores of Colorado, some of the very finest slime
mineral overflowing from the concentration tanks
of the Frue vanners assayed as high as 5000*l.* per
ton in gold and silver. It is obvious that when
very rich mineral exists in the ore, extra care and
expense in close concentration are necessary.

When panning tests on the concentrator tailings
show a distinct head of fine mineral, closer concen-
tration can still be done, if this fine mineral be
rich enough to pay for it. It will be found that
such fine mineral is really no finer or more difficult
to save than much of that already caught in the
concentration tank; its loss is not wholly necessary.
It has escaped contact with the belt surface, in the
same way as fine gold will escape in part from a
short copper table, but be saved in running over a
longer one, having more chances of contact in the
greater distance. In some cases attempts at con-

centration of this mineral from the tailings of the first concentrator have failed, for the reason that one vanner placed below another does not have a good chance, owing to excess of water introduced by the clear water distributor of the first machine. This difficulty can be overcome in several ways, and a consideration of the following suggestions may lead to a more perfect result on many ores now subject to considerable loss in the concentration.

The first and natural course to overcome the crowding of the second vanner is to split the tailings of the upper machine and feed on to two vanners below, and this course will certainly give good results. Another method is to get rid of the excess of water by use of the large settling box previously described; using one box to two, or three, or even four machines, and splitting the thickened discharge on to three or four machines below. Still another course is to size the tailings of the first machine, putting the coarse portion on one vanner and the fine on another below; or even running the fine alone on one vanner and throwing to waste the coarse if the mineral be found mostly in the overflow of the hydraulic sizer. In this latter case the excess of water introduced by the hydraulic sizer may have to be got rid of by using the large settling box, to thicken the pulp before feeding to the tailings machine. This sizing of the tailings is not, as at first glance it may appear, in contradiction

to previous remarks as to the preparation of pulp for
the vanner; because the larger particles of mineral
have already been extracted, and its utility rests in
this case more on the lessening of the work for the
second vanner than on the effects of the sizing
itself as a preparation. In this double concentration
of valuable ores is to be found the true solution of
close concentration, when proper precautions are
taken to give the lower concentrators a fair chance
on the small quantity of fine mineral escaping the
first machines.

In this connection the introduction lately of a
new form of belt surface on the Frue vanner for
special work is likely to be of considerable service.
The improved belt consists of a broken surface,
made up of a number of short rising planes; and
requires a modification in the supporting shaking
frame, and also in the water distributor. The
other points of difference have already been de-
scribed at page 75, as well as the application of the
belt to a coarser class of work.

In the double concentration of valuable ores, or
the treatment of base ores carrying rich silver-bearing
minerals which escape in the concentration of the
mass of sulphurets, the larger capacity of the new
belts would lessen the number of vanners otherwise
needed. For instance, the pulp of five stamps
delivered to one improved belt machine would
be freed of a large percentage of the sulphurets

at once ; and the tailings of this machine split on to two or even three of the plain belt machines would yield nearly the whole of the fine rich mineral which it is possible to separate by concentration. The use of hydraulic separators and large settling boxes, as already suggested, would, in case of coarser crushing than 40-mesh, assist the final operation, and make at once a simple and most perfect mill for any ore which needs finer grinding than rolls are adapted to. A five-stamp battery, with screen of 14 to 30-mesh, will, with a low discharge, prevent much of the sliming of mineral so injurious to close concentration. Take, for illustration, a battery using a screen of 20-mesh ; the improved belt will save all the coarser mineral from the pulp, and the loss will be in fine mineral. This fine mineral can be run off with the overflow of a small shallow hydraulic sizer, discharging at the bottom the coarse rock particles between 20 and 40-mesh, which would not work well on the plain belt vanners below. If the overflow of the separator carries too much water—as probable for two plain belt machines—it is made to pass through the large settling box, of which the thickened pulp discharge is divided on to the two belts below. The overflow of the large settling box will not contain any mineral likely to be saved by a concentrator. In certain special cases, where some of the fine mineral escaping the upper improved

belt is still heavy enough to settle with the coarse
sand in the hydraulic separator, this discharge can
be run on a second improved belt below, and the
overflow go through the large settling tank, as
before explained, to one or two of the plain belt
machines.   For if the mineral will settle against
the upward current of the hydraulic sizer, it will
separate readily on the improved belt, although it
has accidentally escaped the first one.   In each
case it is necessary to experiment with the par-
ticular ore, to determine the best size of screen
(using always the coarsest possible), and also to
decide the best method of using the hydraulic sizer,
so as to either drive the whole of the mineral into
the overflow, or allow part to settle with the coarse
sand discharge, according as this last is run to waste
or worked over again.

In advising the use of the large settling box it is
intended that the siphon discharge, as fully de-
scribed, shall be used.   Millmen may be frightened
at the height of this box, and the consequent large
fall in mill site apparently necessary; but the actual
loss of fall is not over 3 feet at most, by use of the
siphon discharge, and the other advantages of this
have already been explained.

At the Silver King Mine, in Arizona, a complex
silver ore was concentrated for several successive
years by stamping over a single row of vanners,
and very close work was done, with production of

concentrates containing 800 to 1200 oz. of silver per ton. The ore contained native silver, sulphide of silver, ruby silver, brittle silver, argentiferous grey copper, galena, and zinc blende, with some pyrites. To further increase the percentage saved, a row of six vanners with belts 6 feet wide, were placed below the twelve upper machines with the regular 4-foot belts. These lower machines did good work on the tailings of the first, though the concentrates were of lower grade and consisted largely of zinc blende. The tailings from the upper concentrators assayed 4·11 oz. silver per ton. The lower machines treated 12½ tons each daily, and careful assays, made in working 10,178 tons of ore, showed that the final tailings assayed only 2·03 oz., or 7½ per cent. of the original value of the ore worked. These results show clearly that tailings in some cases may be reduced 50 per cent. in value by a proper double concentration; and in this particular case, an actual saving of 21,509 ounces of silver was made from the tailings of 10,178 tons of ore, with a merely nominal increase in the daily expenses of the mill for 4½ months' work.

The good work done by the vanner has rather blinded millmen to attempting any improvements by double concentration. It is generally assumed that if two machines are placed to 5 stamps, the last hing has been done in precautions to insure close

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work; and it is believed either that the mineral then escaping is too fine for concentration, or that some new invention must be awaited in concentrators. This is in effect the somewhat absurd conclusion, that because the machine does remarkably close work on fine mineral, it must not be used . twice over. In gold milling, if fine gold escapes an 8-feet plate, an additional length is often used with success; and it is not assumed, because 8 feet is long enough on most ores, that the utility of copper plates ends with this length. In some cases of valuable ores, millmen have used an extra vanner to each five stamps, making three; and, by this, have increased the saving in a marked degree. The great test of the possibility of still further improvement is by hand-panning on the tailings. If a distinct head of mineral is easily shown, closer work can be done. The subject of hand tests has been treated at page 9. It will be found that the white enamelled placque, or the " batea," is greatly preferable to the gold pan for such tests, and the " batea " can be used by anyone with very little practice. An examination of the excessively fine concentrates saved in regular working by a Frue vanner, will convince anyone that the fine mineral shown in hand-panning the tailings is not a necessary loss in concentration, but an accidental loss, which can . be reduced—if profitable so to do— by a second treatment. This is an immediately

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available remedy; and commends itself to common sense as compared with waiting for the invention of an absolutely perfect concentrator—which inventors may dream of, but practical men will not expect to see.

CONCENTRATION TOOLS.

VANNING SHOVEL.
Scale 1 inch to foot.
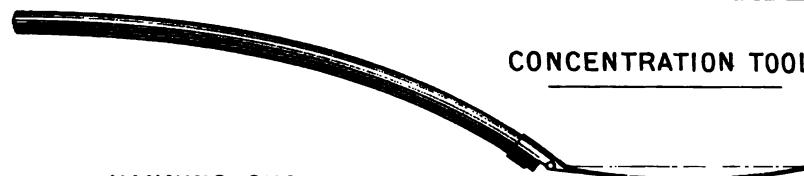
VANNER PLACQUE.
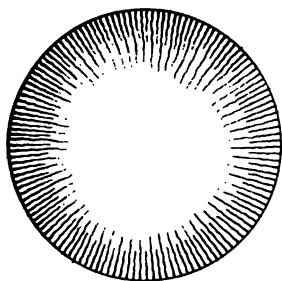
ENAMELLED IRON "BATEA".

GOLD PAN.   *Scale 1½ inch to foot.*
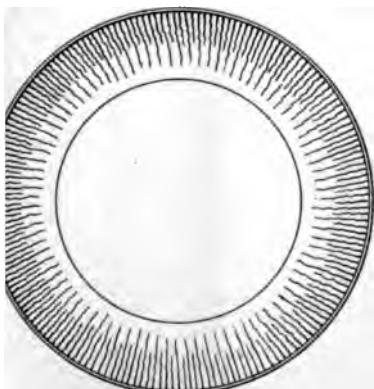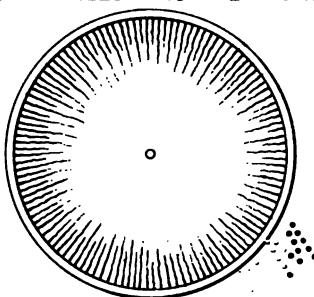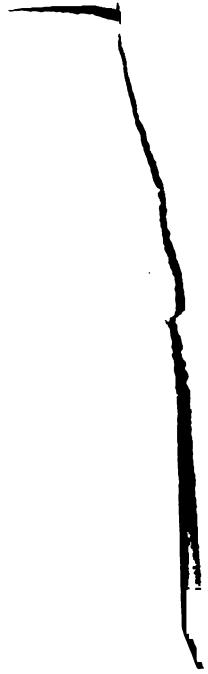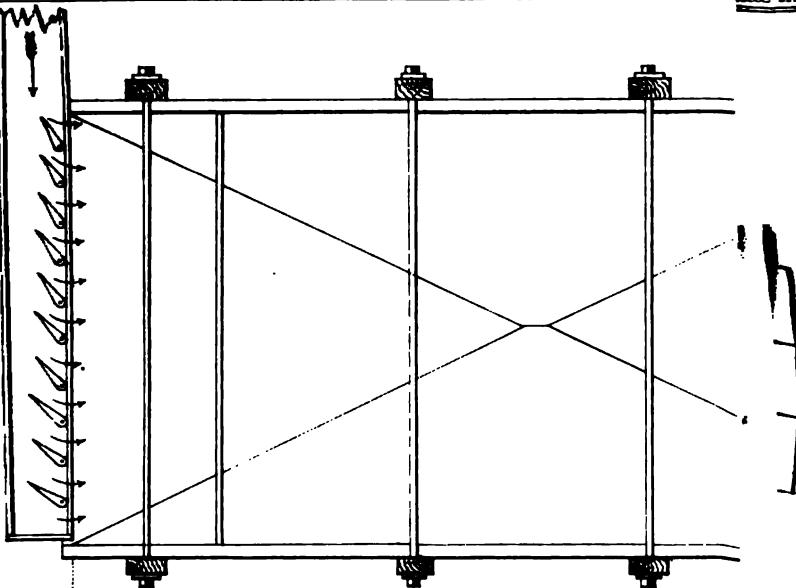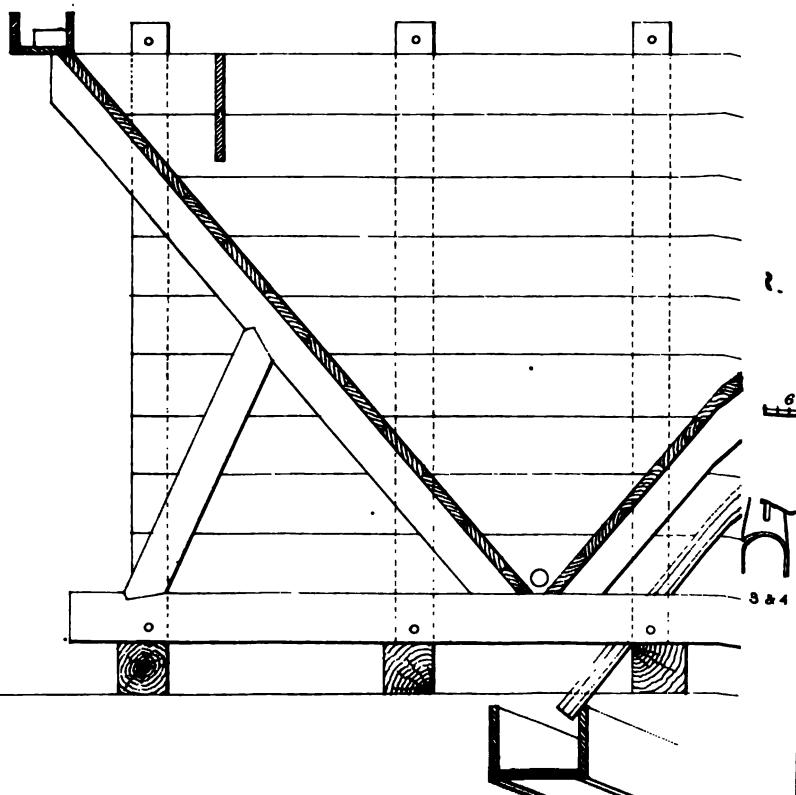
MEXICAN WOODEN "BATEA."

13 ft

3 & 4

Plate III.

SHIELD OF 3 & 4

Plate II

SETTLING BOX.

6 ft

Scale ⅜ inch to Ft

6   7   8   9   10
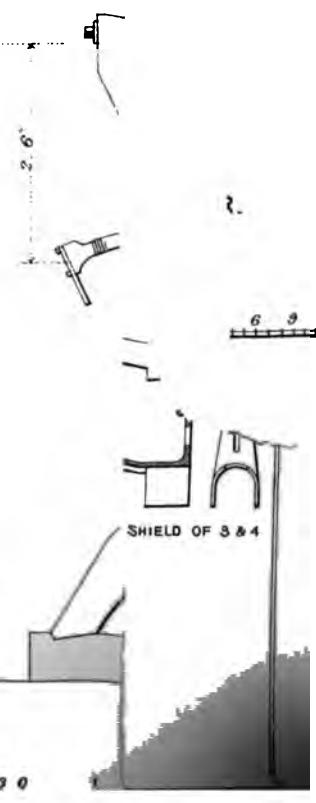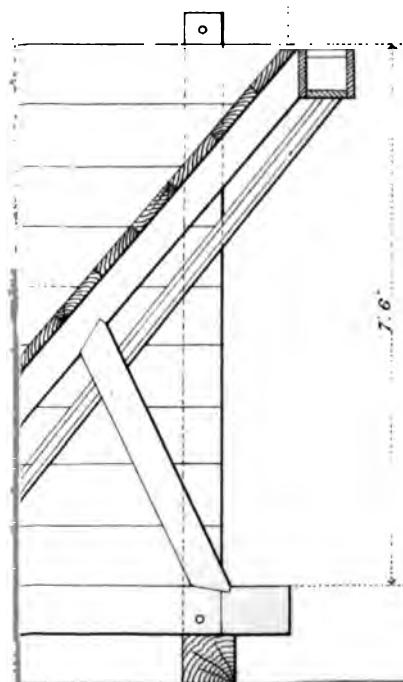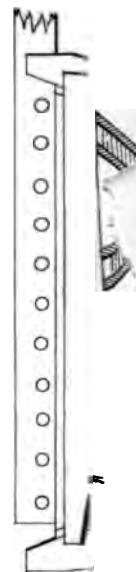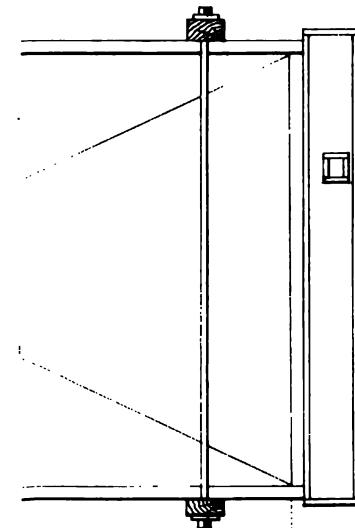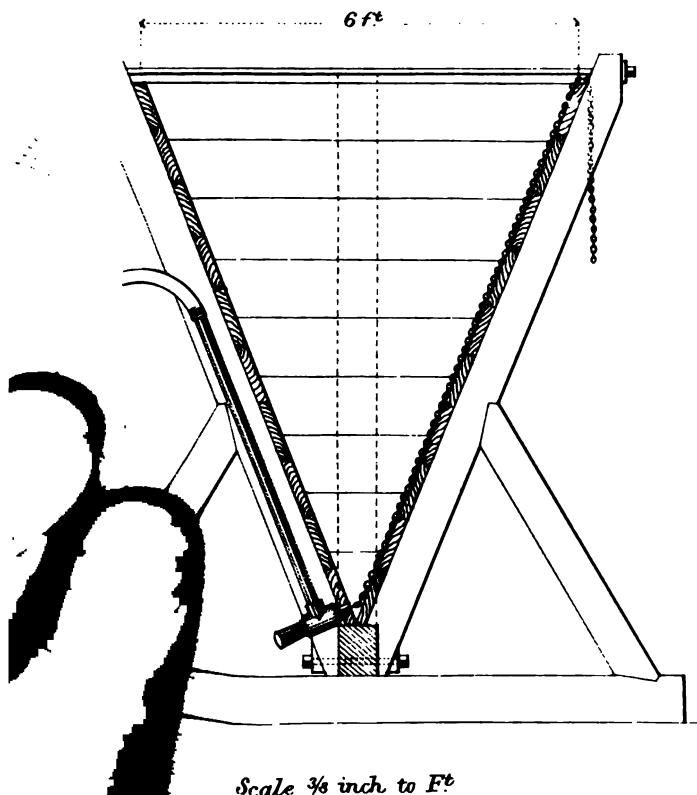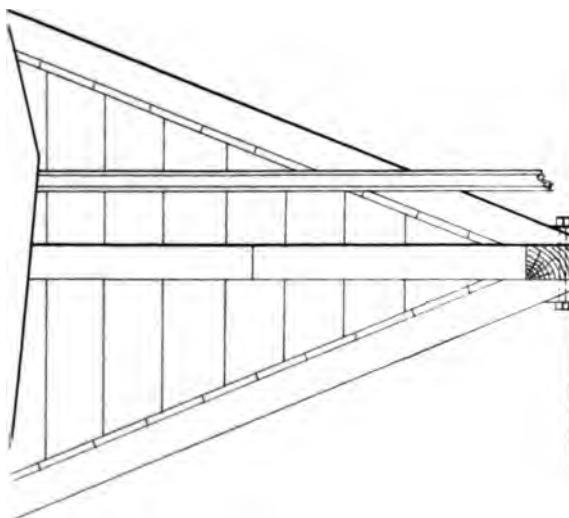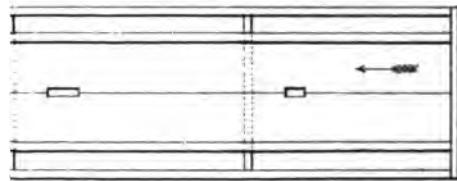
OR TROUGH SEPARATOR.

Fig. 3.

¾″ ½″

RATOR.

Scale ¾″ = 1

SHIELD OF 1 & 2

2   SECTION THROUGH 3 & 4

SHIELD OF 3 & 4

Scale ¾″ = 1 foot.

SECTION THROUGH A.B.
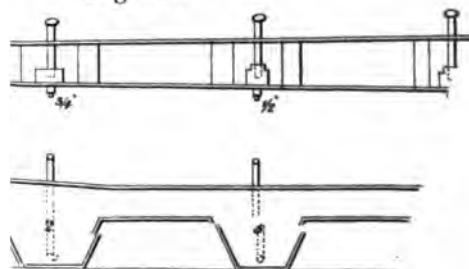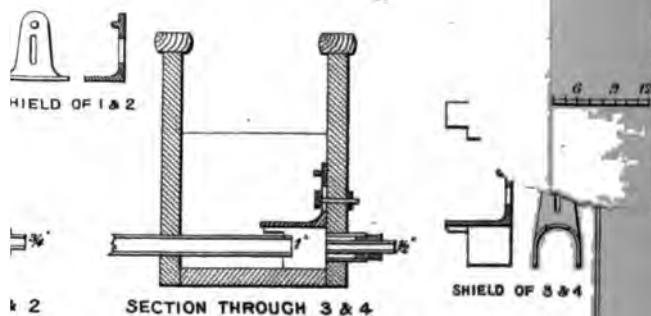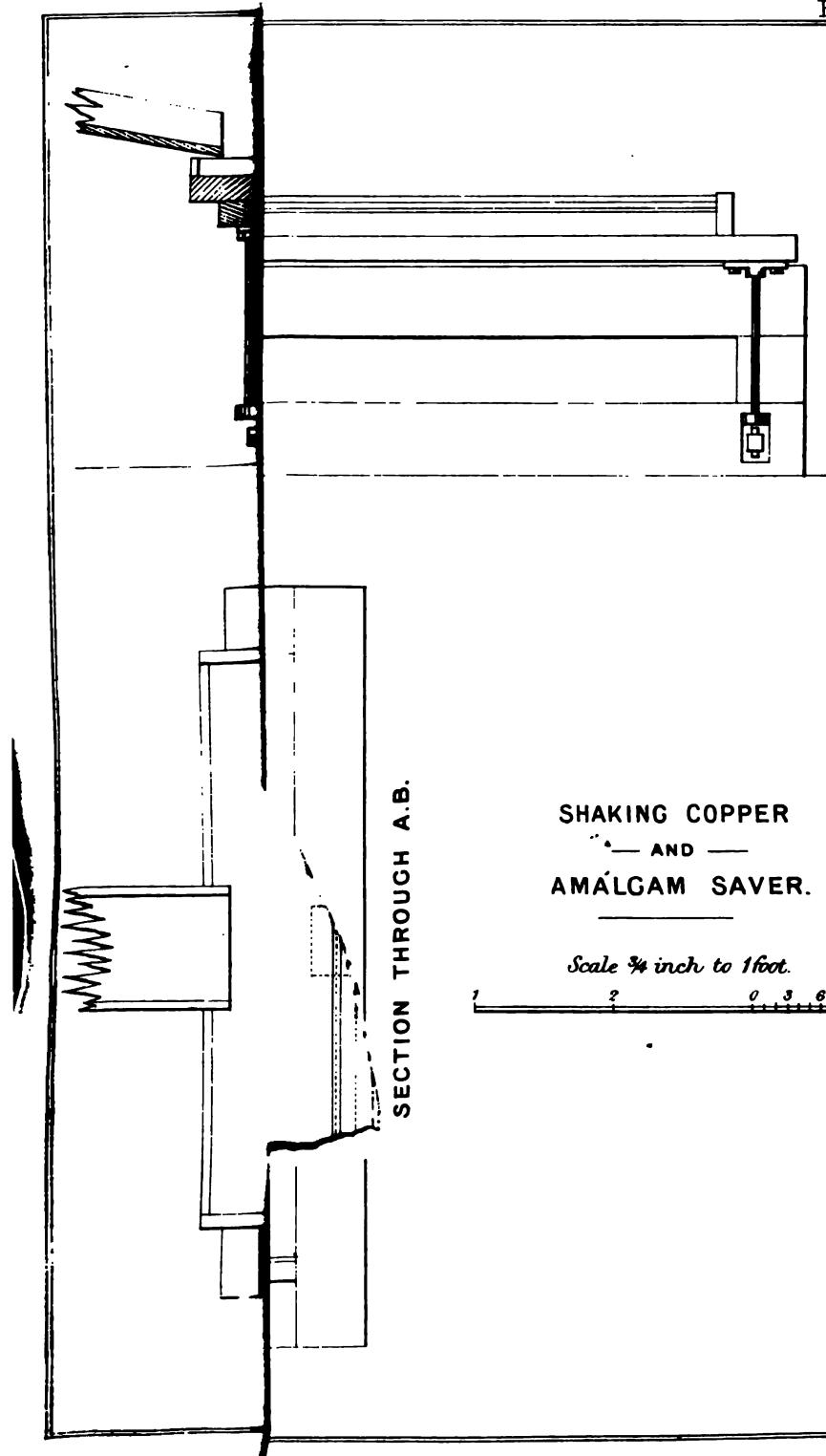
SHAKING COPPER

— AND —

AMÁLGAM SAVER.

Scale ¾ inch to 1 foot.

1   2   0   3   6